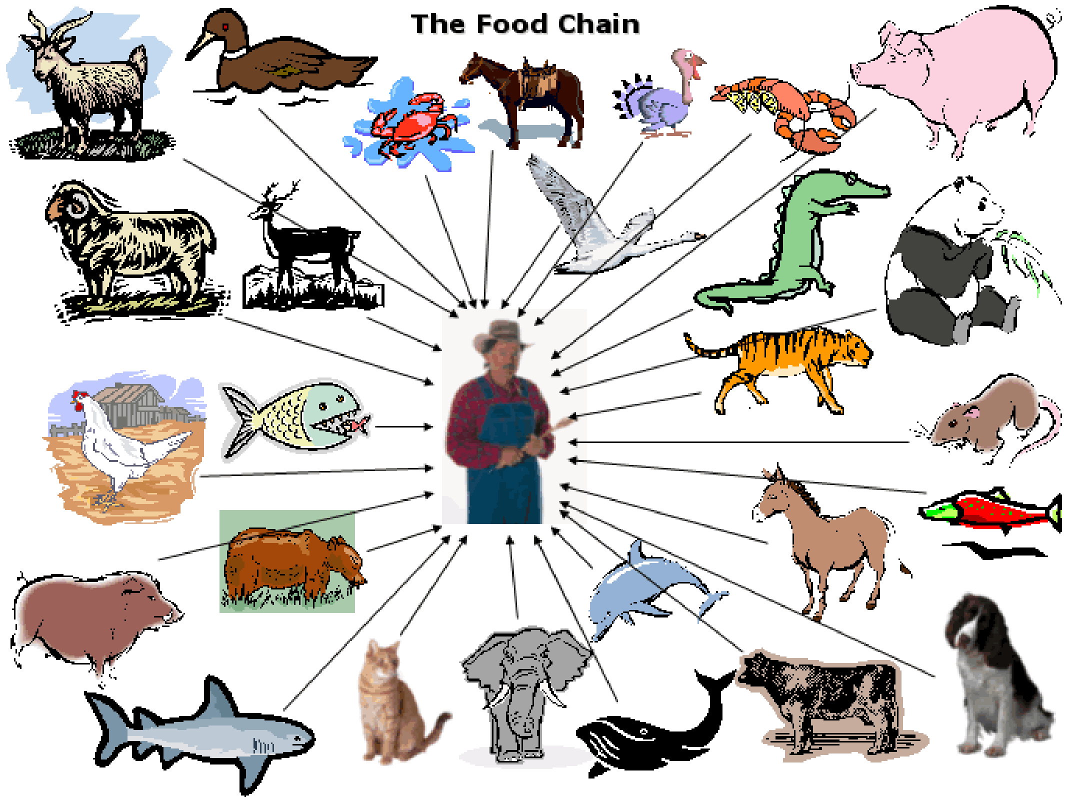
Herps in Ecosystems



Competition

- Types of competition
- Competition and the niche
- Competitive exclusion principle
- Character displacement
- The problem with competition

Competition

- Types of competition
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Competition

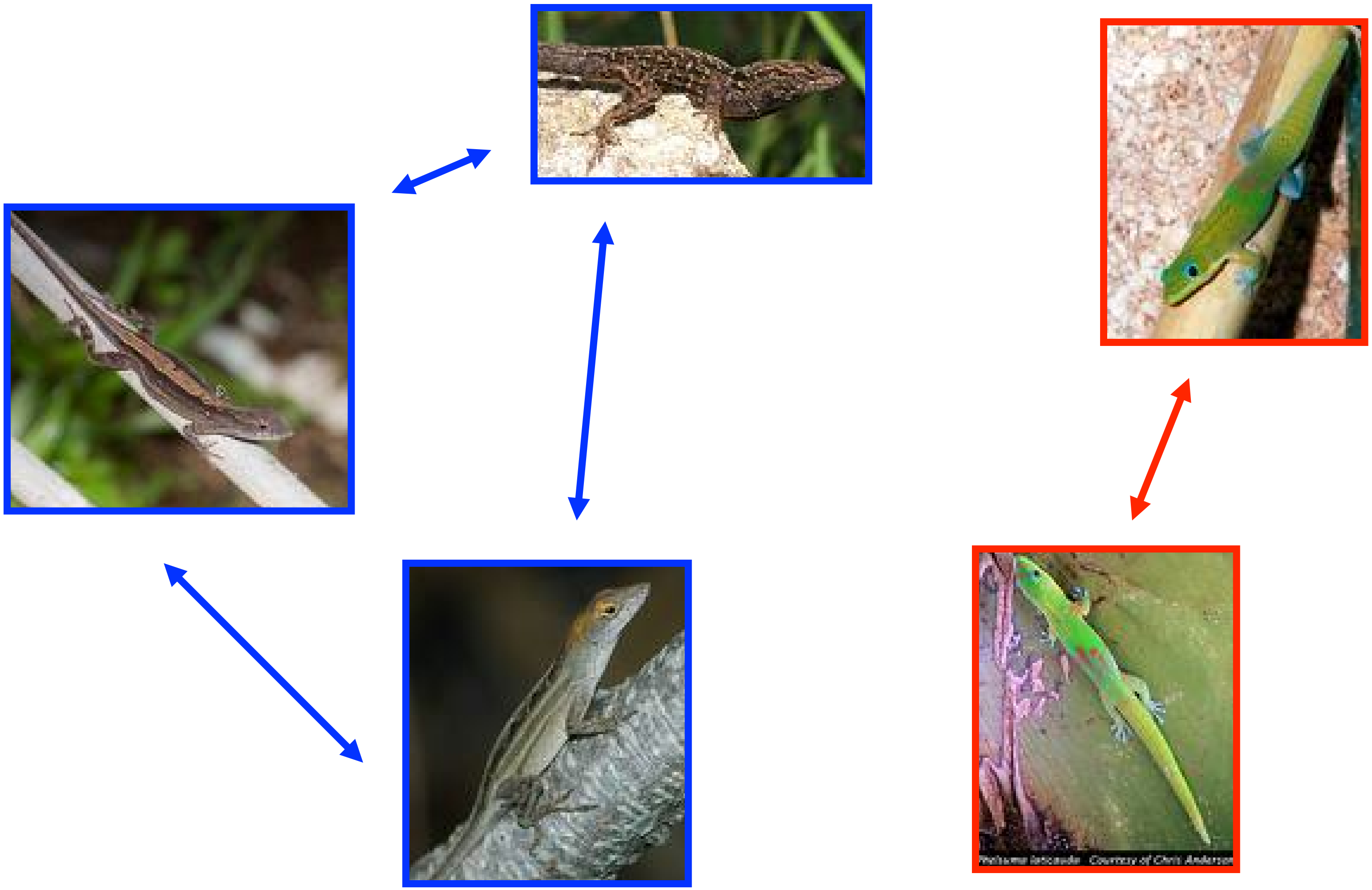
- An interaction between two (or more) species where each has a negative effect on the fitness of the other
- Examples:
  - Geckos competing for insect prey items
  - Painted turtles competing for basking sites

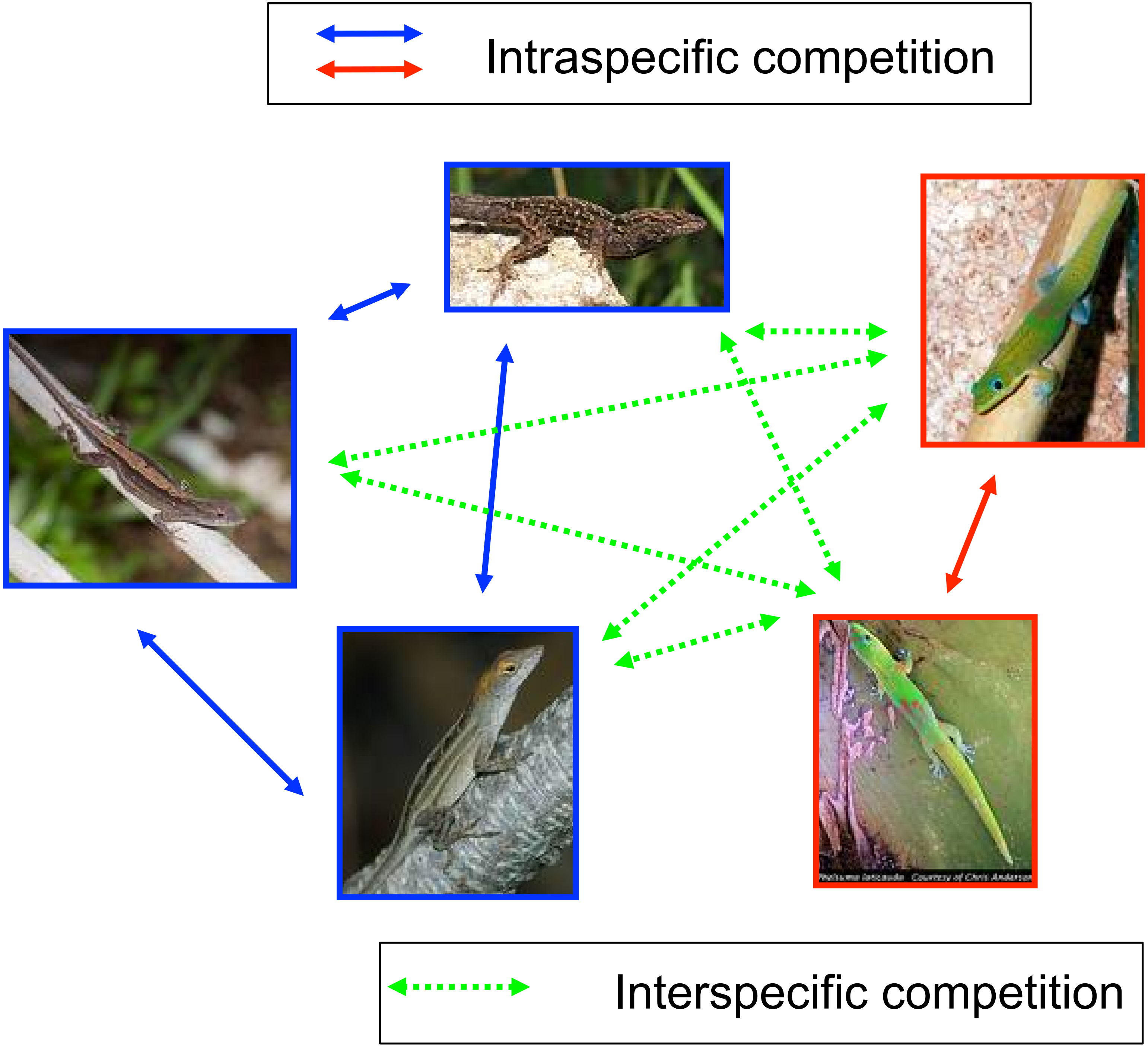
Painted turtles (*Chrysemys picta*)

Competition

- Competition can occur both within species (intraspecific competition) and between species (interspecific competition)
- Both are important in ecological and evolutionary theory

Intraspecific competition




Intraspecific competition
Interspecific competition

Competition and Coexistence

- All else being equal, species will coexist if interspecific competition is weaker than intraspecific competition
- This will allow species to increase when rare and prevent competitive exclusion

Main Types of Competition

- Interference competition
  - Direct mechanism of competition where individuals interact aggressively with each other
  - Example: territorial defense


Photos by Dennis Hansen

Main Types of Competition

- Interference competition
  - Direct mechanism of competition where individuals interact aggressively with each other
  - Example: territorial defense
- Exploitation competition:
  - Indirect mechanism of competition where individuals affect each other through their use of a limiting resource
  - Example: invertebrate feeding by terrestrial salamanders

Mandarin Salamander, Tylototriton verrucosus, eating a worm

Main Types of Competition

- Both of these types can be either intra- or interspecific
- Examples:
  - Two brown anoles aggressively fight over a perch site

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Main Types of Competition

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  - *Interspecific exploitation competition*

Competition

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Competition and the Niche

- The ecological niche of a species has two components:
  - The species' **requirements**: what does that species need to survive?
  - The species' **impacts**: what effect does that species have on the ecosystem?

Aspects of the Herp Niche

- Temporal niche - what time of day is the species active?

Aspects of the Herp Niche

- Spatial niche - where do they live?

Aspects of the Herp Niche

- Trophic niche - what do they eat?

Aspects of the Herp Niche

- Predatory niche - How do they escape predators?

Competition

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Competition Matters

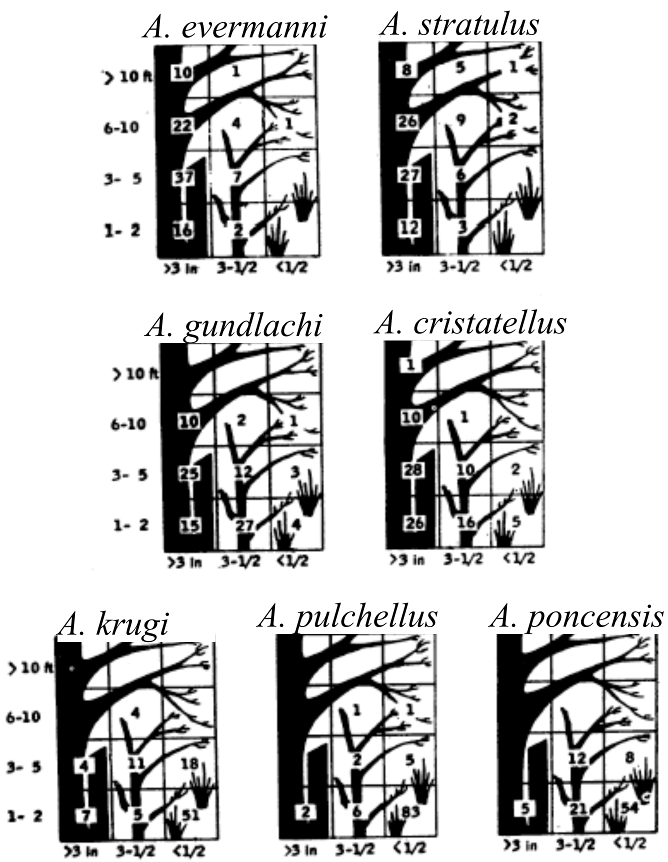
- **Gauss's competitive exclusion principle** states that two species competing for exactly the same resources cannot coexist
- Two species in the same place cannot have the same niche
- One will eventually outcompete the other

Competition's Consequences

Predictions:

1. **Niche partitioning**: When species live together, they should use different resources
2. **Habitat shifts:** Species resource use should be more different in sympatry than in allopatry
3. **Direct tests:** Experiments should show that species have effects on each other

Niche Partitioning in *Anolis*

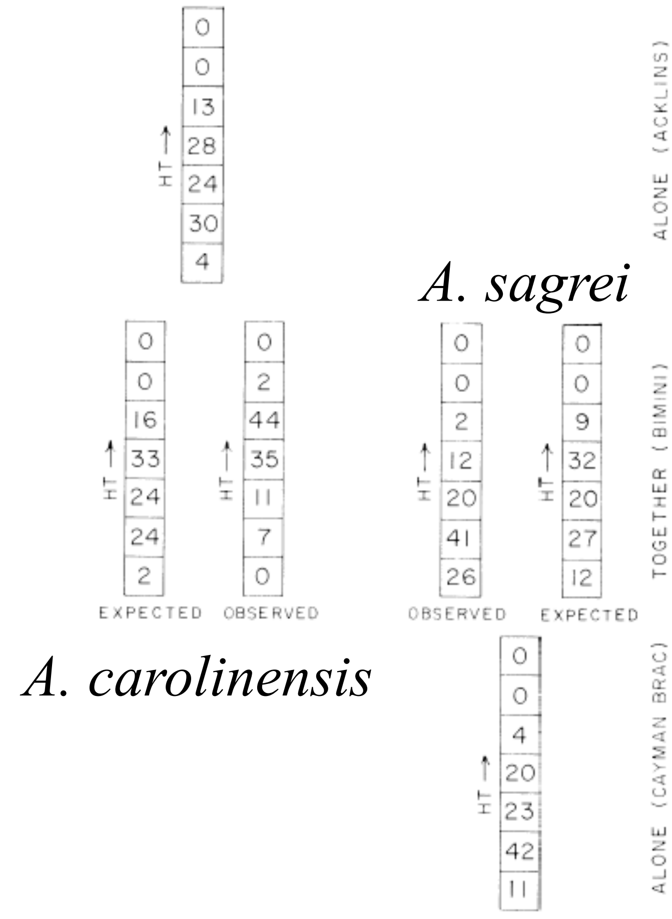


(Rand 1964)

- Sympatric species of anoles use different microhabitats
- Perch height
- Perch diameter

Habitat Shifts in *Anolis*

- Species shift their microhabitat use to become more different in sympatry compared to allopatry



(Schoener 1975)

Sympatric Species Compete in *Anolis*

• Experiments offer more definitive evidence for competition

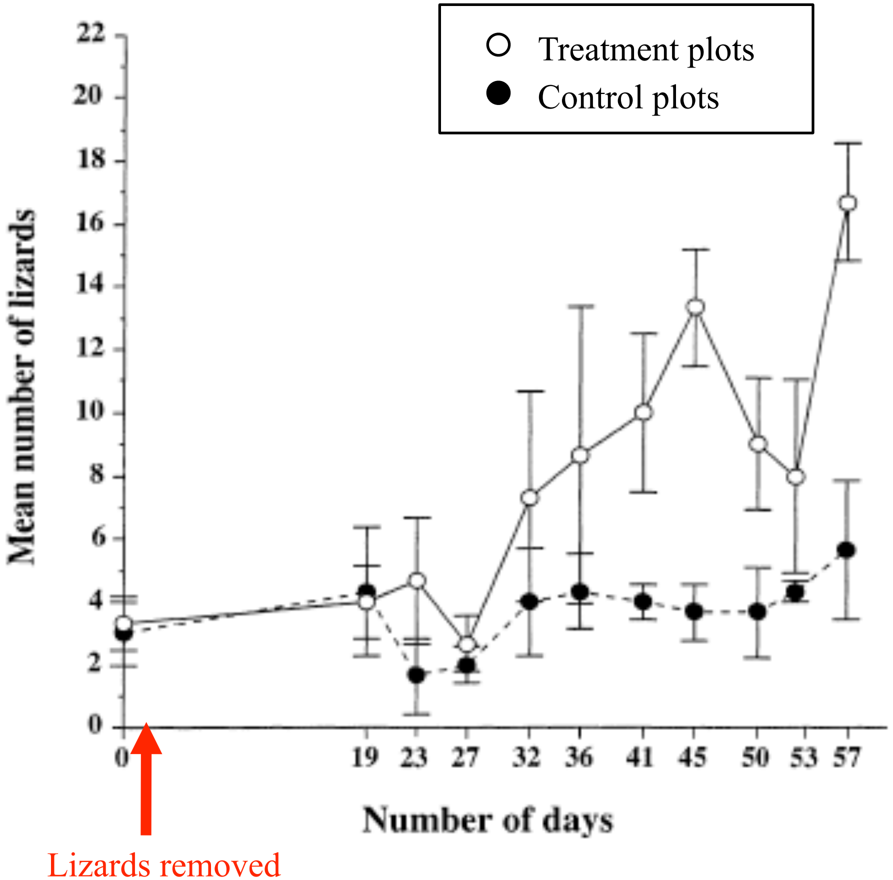
In anoles, competition affects:

• Abundance

Leal et al. 1998

• Microhabitat use and diet

Pacala and Roughgarden 1982
Roughgarden et al. 1984
Pacala 1985



Leal et al. 1998

Competition

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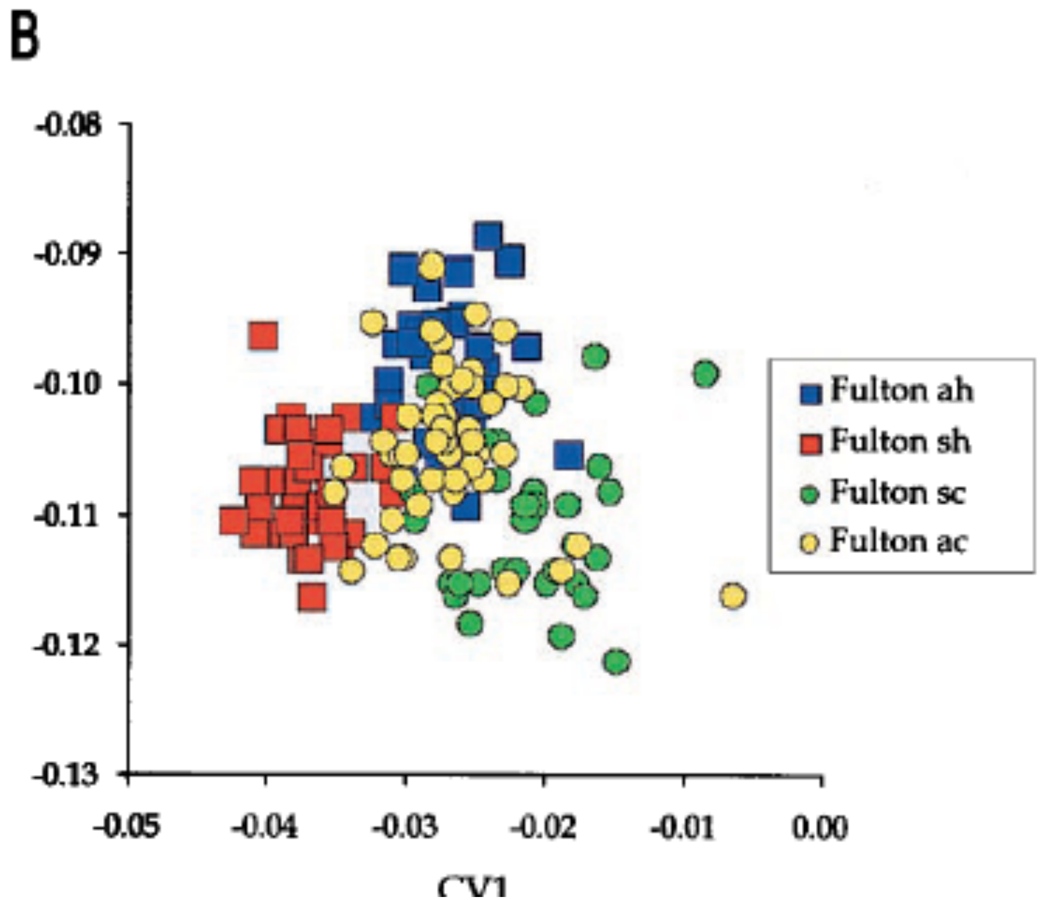
Character Displacement

- Habitat shifts in sympatry may lead to divergent selection between the two species
- They may evolve phenotypic differences in sympatry
- This is called character displacement

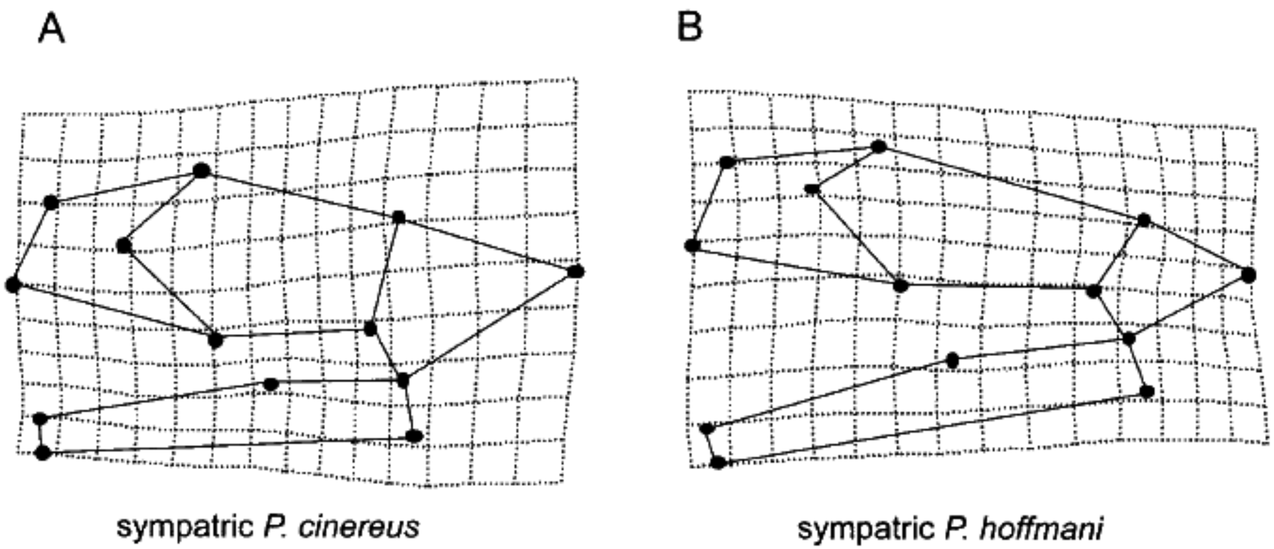
Character Displacement in Salamanders



Species differ, but only in sympatry

(Adams and Rohlf 2000)

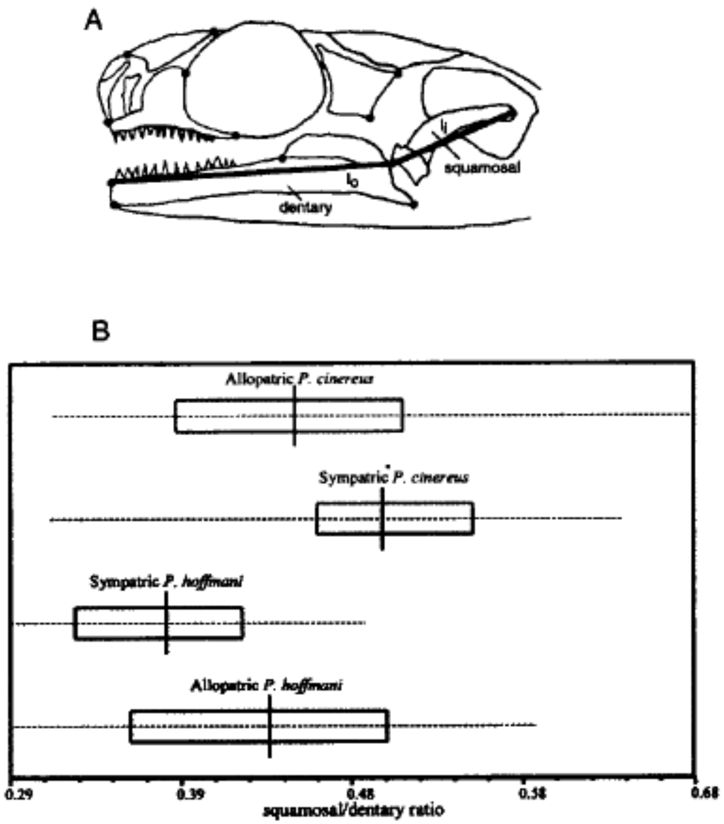
Character Displacement in Salamanders



Sympatric species have different head shape…

(Adams and Rohlf 2000)

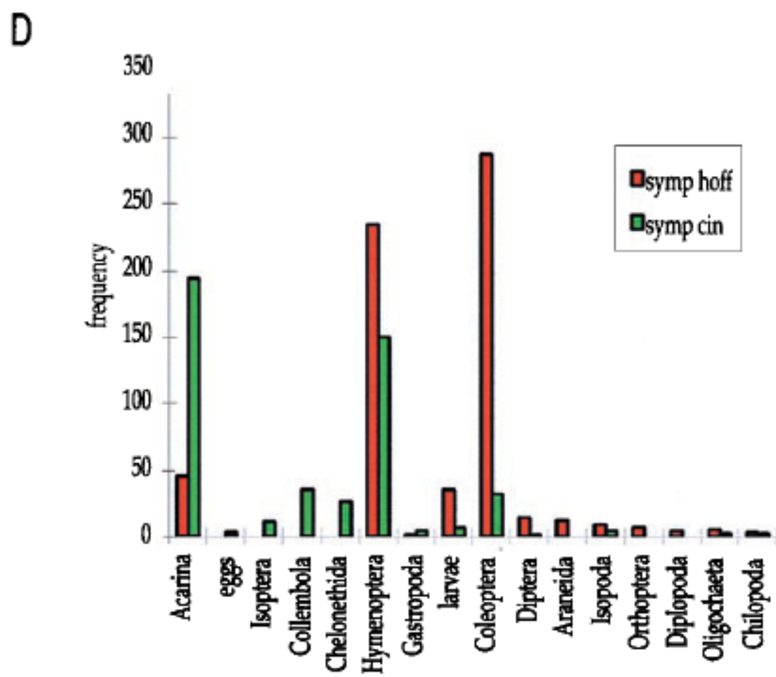
Character Displacement in Salamanders



Sympatric species have different bite force…

(Adams and Rohlf 2000)

Character Displacement in Salamanders



Sympatric species have different diet

(Adams and Rohlf 2000)

Competition

- Types of competition
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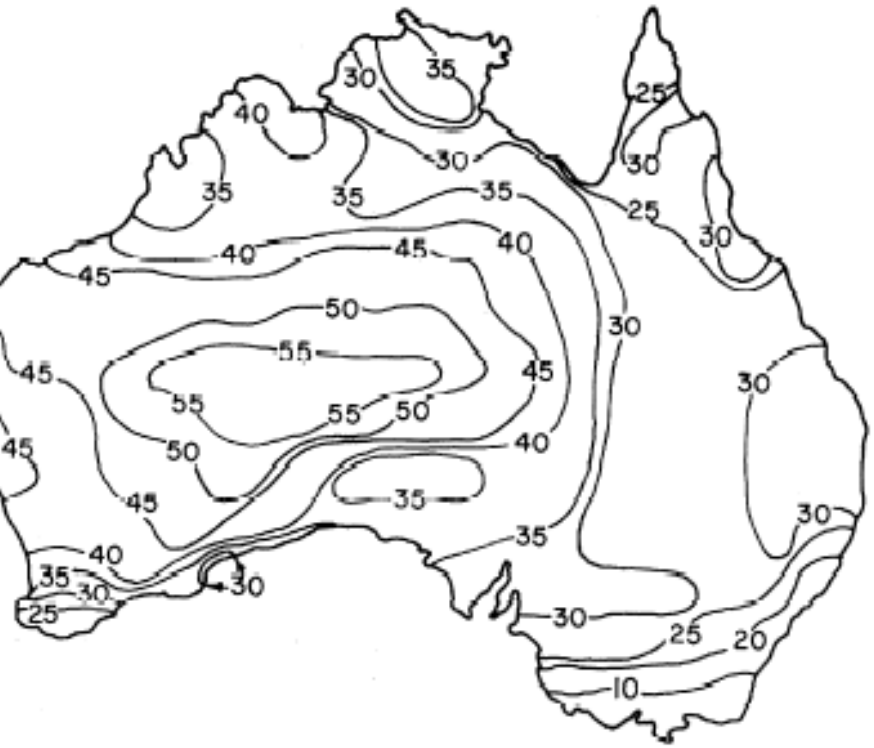
The problem with competition

- The competitive exclusion principle is not testable in practice
- All species differ in some way, if you measure enough
- There are other ways to get species to live together - to infinity!
- Examples of exclusion are rare, even in invasive species

Why are there so many species?

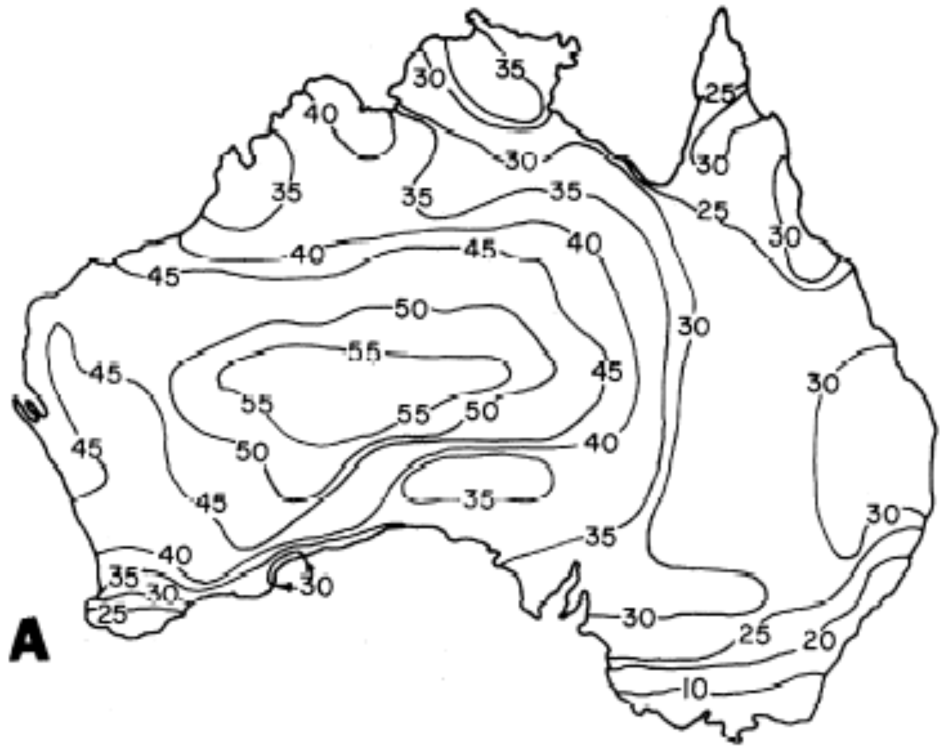


A

Species Diversity of Nonskink Lizards in Australia

(Schall & Pianka 1978)

Why are there so FEW species?



Species Diversity of Nonskink Lizards in Australia

(Schall & Pianka 1978)

Modern Community Ecology

- Modern community ecology seeks to integrate all of these ideas
- Species interact through competition, but the magnitude may be weak, and vary through space and time
- Models can predict any number of species - so why do we get the exact number that we see in nature?

Herps in the food web

- Predation - why is it important?
- How do herps avoid predators?

Some herp predators

Invertebrates

Other herps

Birds

Mammals

Why is predation important?

Secretary bird
Sagittarius serpentarius

Striped Skink
Mabuya striata

Why is predation important?

Secretary bird
Sagittarius serpentarius

Striped Skink
Mabuya striata

Why is predation important?

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Striped Skink
Mabuya striata

Secretary bird
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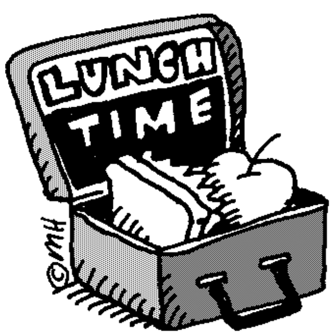

The “life-dinner” principle

- Interactions between predators and prey are frequently asymmetric
- Predator gains or loses a meal
- Prey gains or loses its life
- Selection for antipredator defense mechanisms can be strong

Defense mechanisms

- Avoid detection
- Avoid capture
- Avoid consumption
- Signal inedibility (or mimic)

Defense mechanisms

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Avoid detection

- Crypsis is common in herps
- Resemblance can be general or specific
- Example: green lizards are usually arboreal

Avoid detection

- Crypsis is common in herps
- Resemblance can be general or specific
- Example: green lizards are usually arboreal
- Green and grey Pacific tree frogs (*Pseudacris regilla*) will move to places where they match the substrate

Phrynosoma modestum, round-tailed horned lizard

Uroplatus sikorae
Mossy leaf-tailed gecko

Eyelash Leaf Frog *Ceratobatrachus guentheri*

Avoid detection

- Moderate behavior in the presence of predators - be quiet, hide, etc.
- This may have a cost
- Less food or mates
- Organisms have to balance costs and benefits

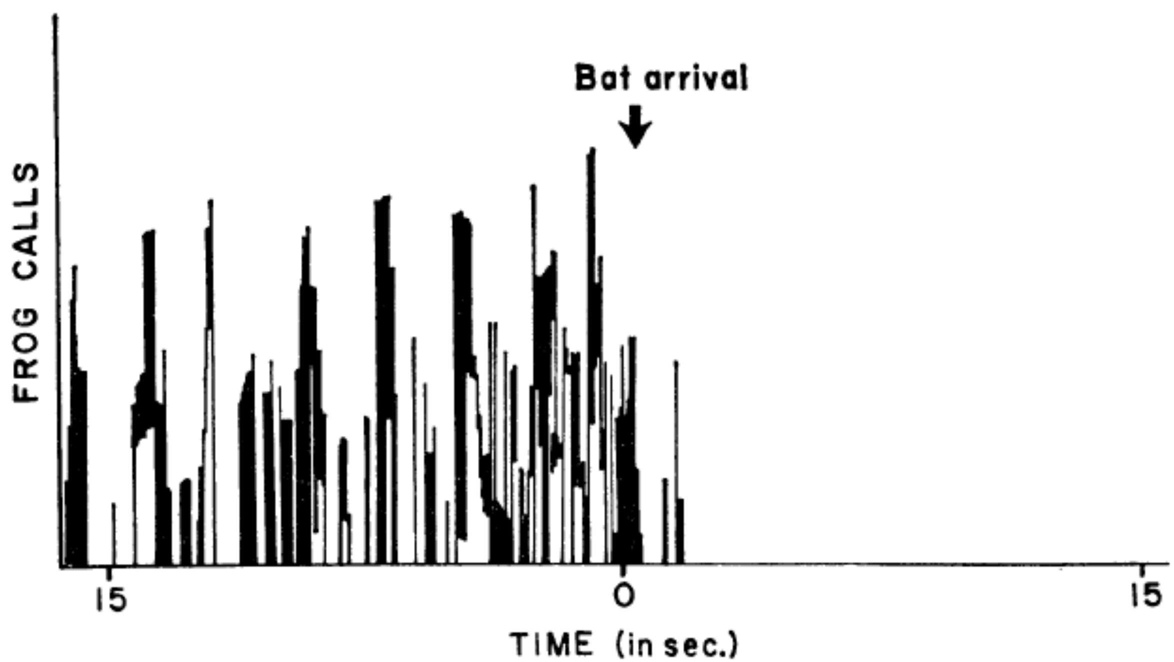
Example: Túngara frog

Physalaemus pustulosus

Example: Túngara frog

Fringe-lipped bat
Trachops cirrhosus

Example: Túngara frog

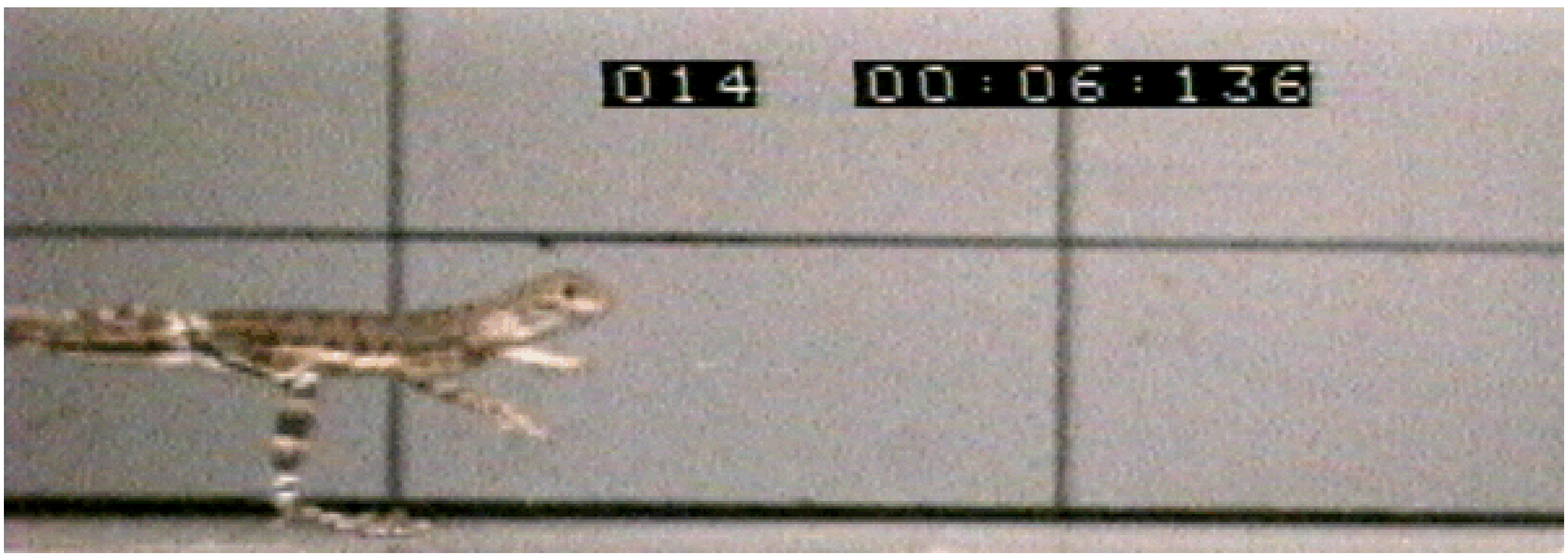


Defense mechanisms

- Avoid detection
- Avoid capture
- Avoid consumption
- Signal inedibility (or mimic)

Avoid Capture

- Run away



Zebra-tailed lizard, *Callisaurus draconoides,* 4 m/s (about 9 mph)

Avoid Capture

- Glide

Draco maculatus


8:29:42AM

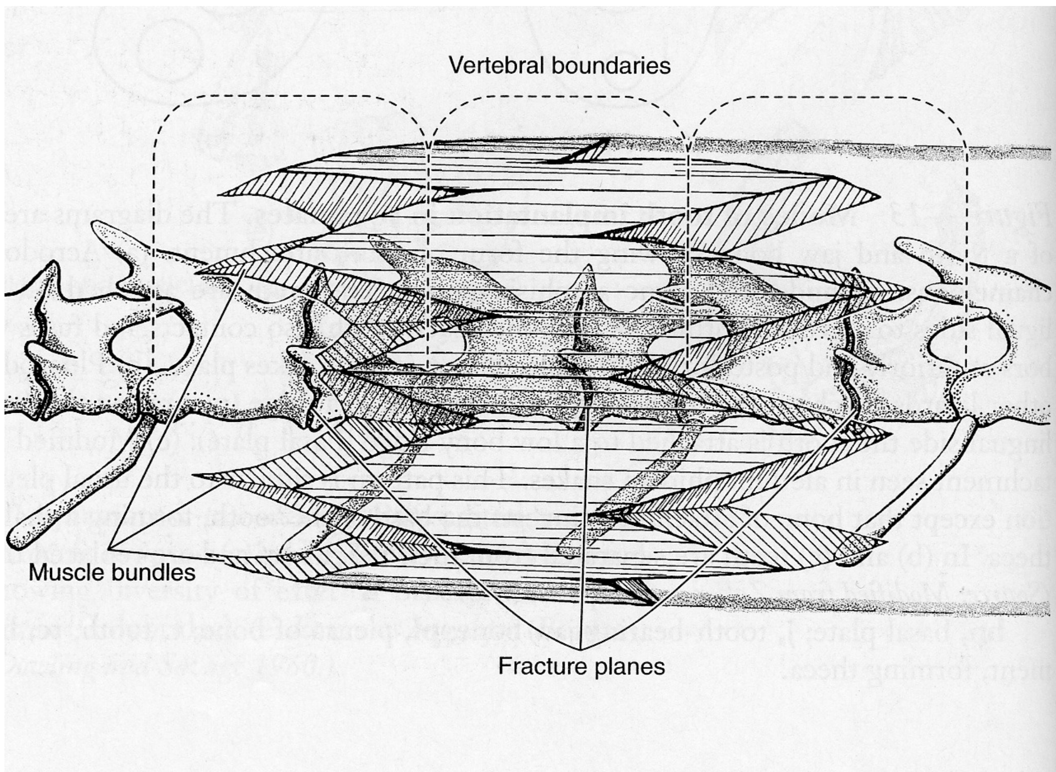

8:29:42AM

Avoid Capture

- Confuse

Uroplatus fimbriatus

Caudal autotomy

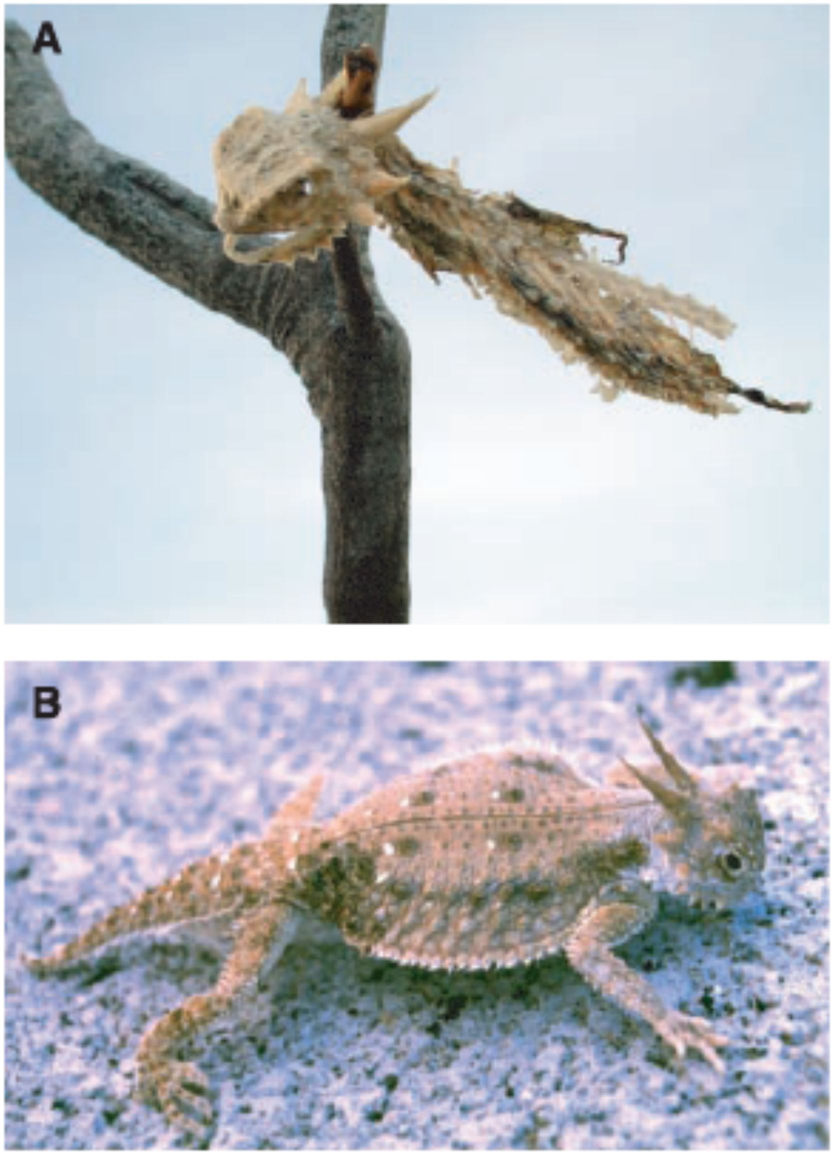


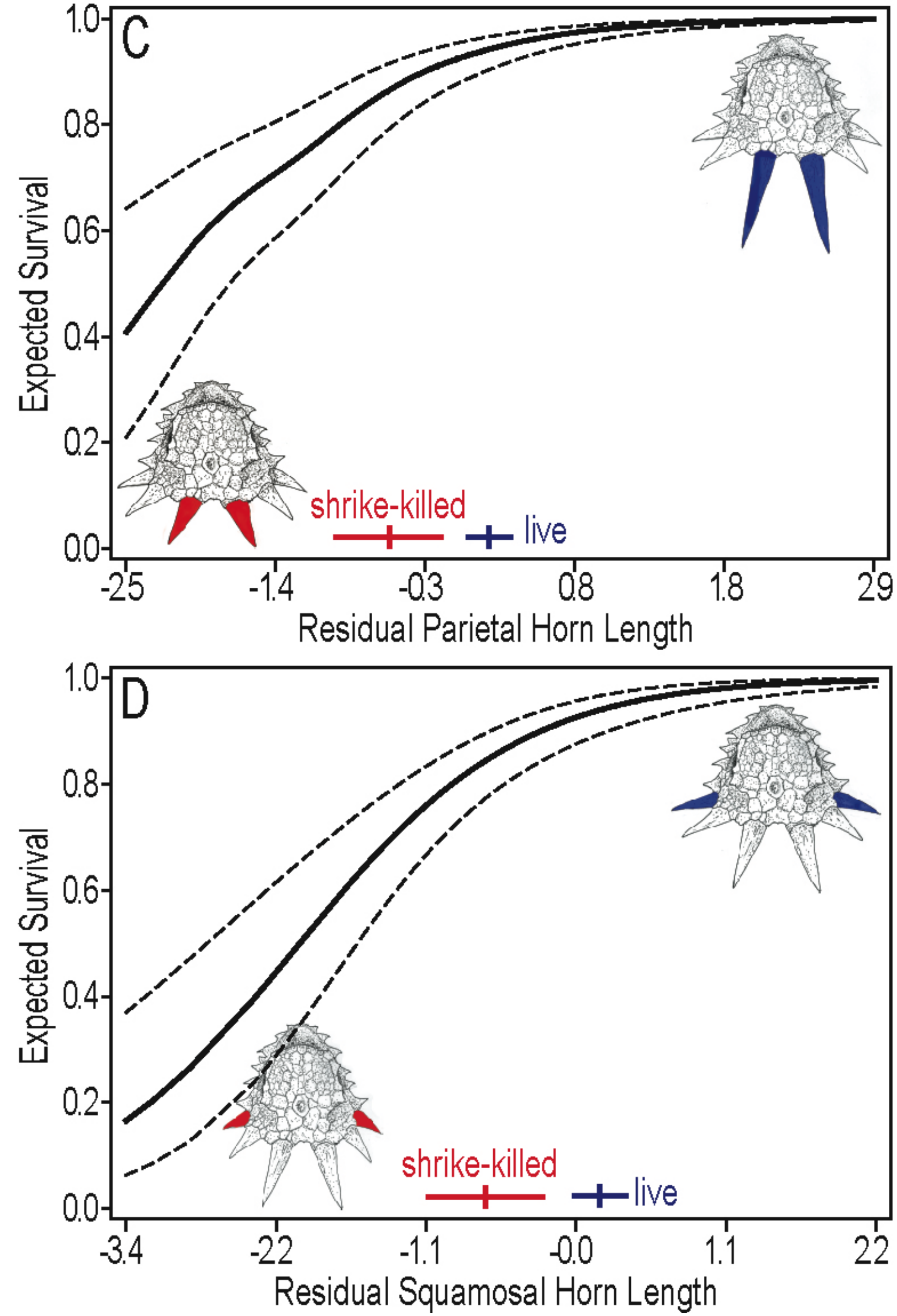
Avoid capture

- Flee (run, jump, glide, swim…)
- Confuse
- Threaten
- Drop your tail

Defense mechanisms

- Avoid detection
- Avoid capture
- Avoid consumption
- Signal inedibility (or mimic)





Phrynosoma mcalli

Toxicity

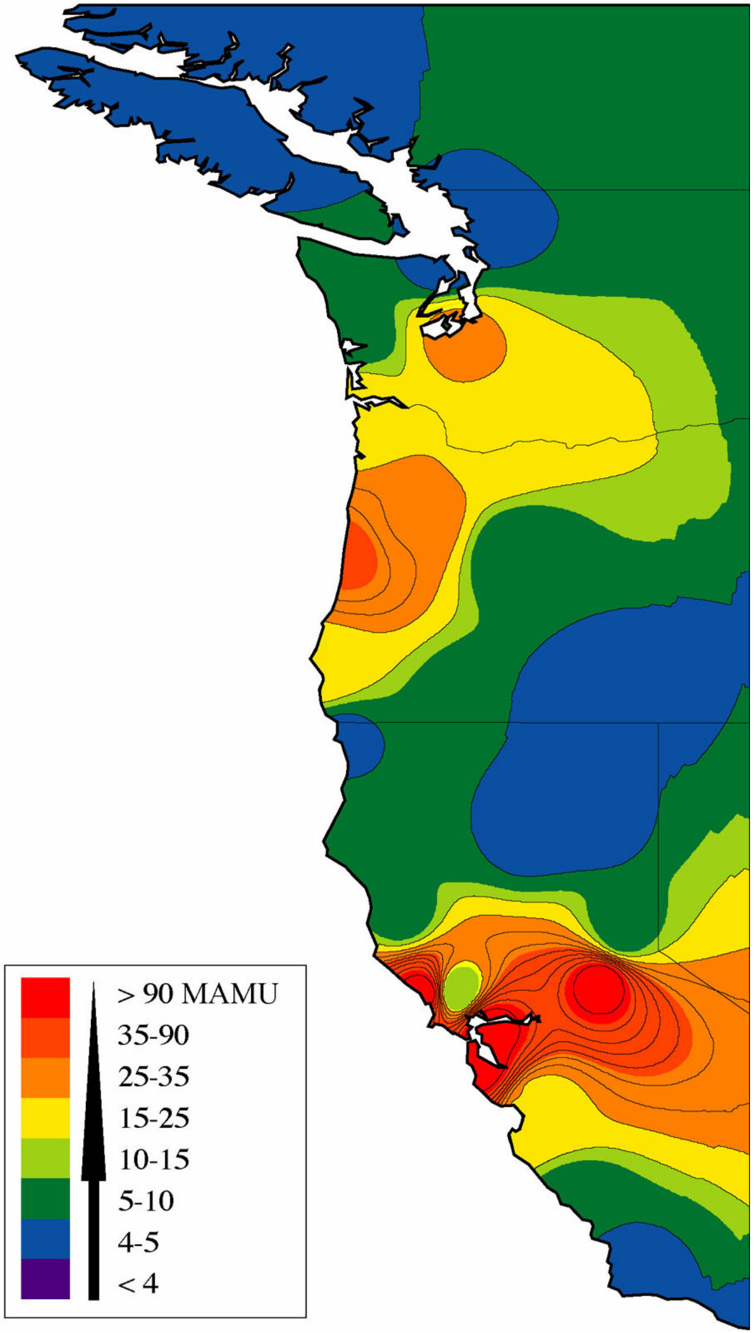
- Many amphibians use toxicity as a defense
- Dart poison frogs (*Phyllobates*), bufonids (A*telopus*), newts (*Salamandra, Notophthalmus, Taricha*)

Toad (*Atelopus spumarius*)

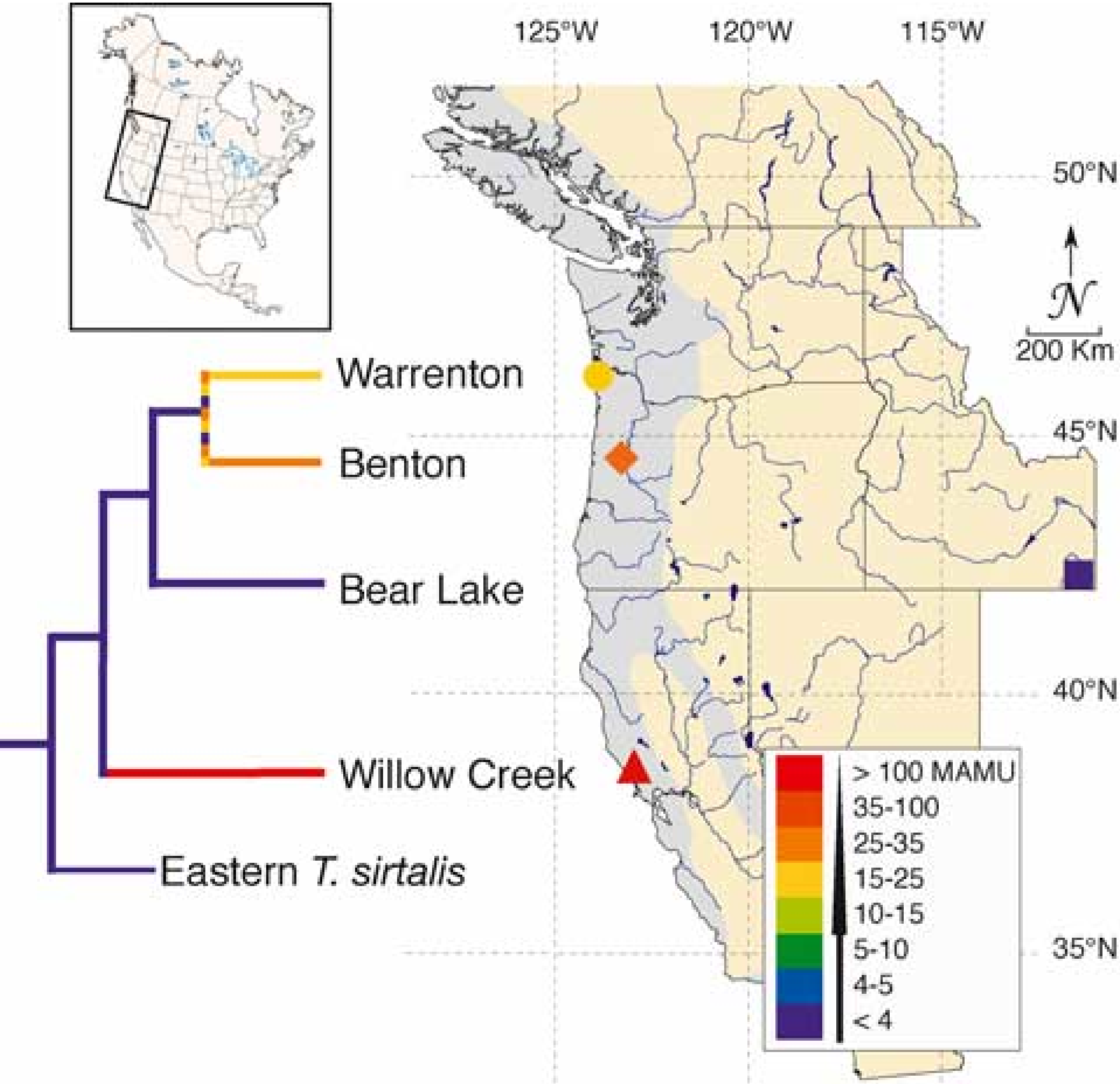
Taricha and TTX

- *Taricha granulosa* (rough-skinned newt) has tetrodotoxin (TTX) in skin
- One newt has enough to kill 25,000 rats

- Garter snake (*Thamnophis sirtalis*) feeding on *Taricha*



- Newt toxicity varies from place to place



- Garter snake resistance parallels newt toxicity

Defense mechanisms

- Avoid detection
- Avoid capture
- Avoid consumption
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Why is predation important?

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Striped Skink
Mabuya striata

Secretary bird
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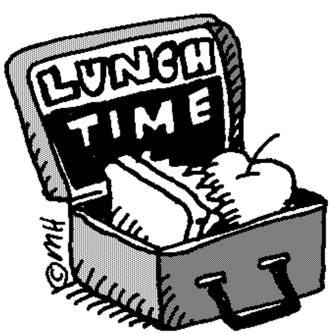

Why is predation important?

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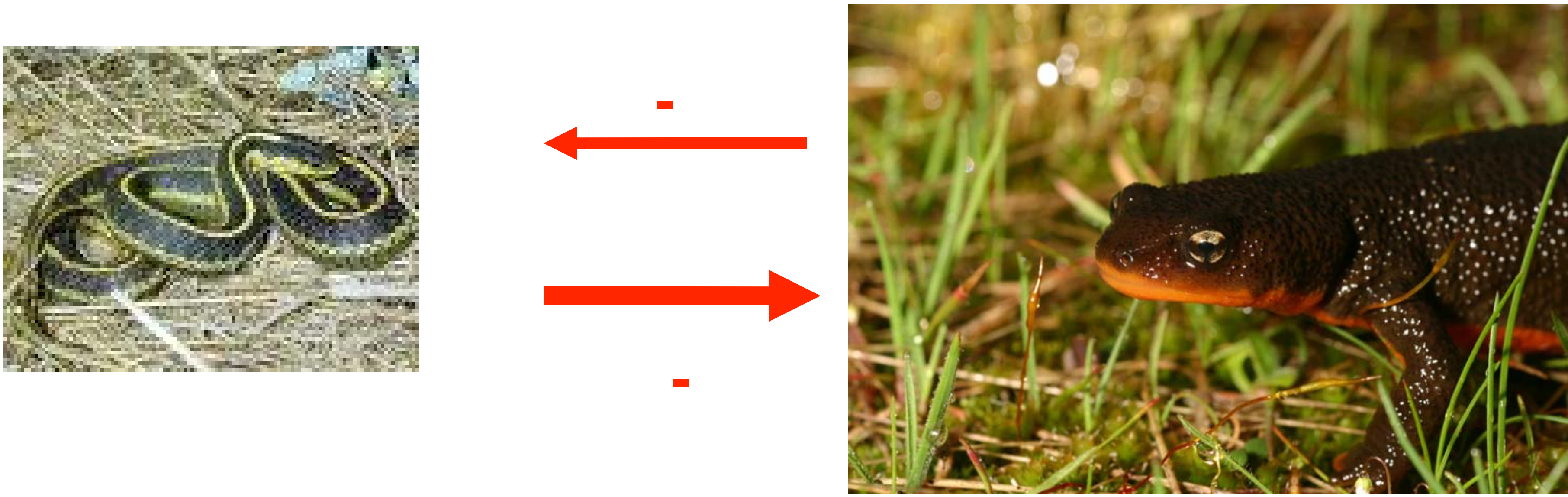


Signaling inedibility

- Problem with being toxic: you have to eat me to find out
- Poisonous herps usually have warning signals that they send to potential predators
- **Aposematic coloration** = bright colors that warn of toxicity

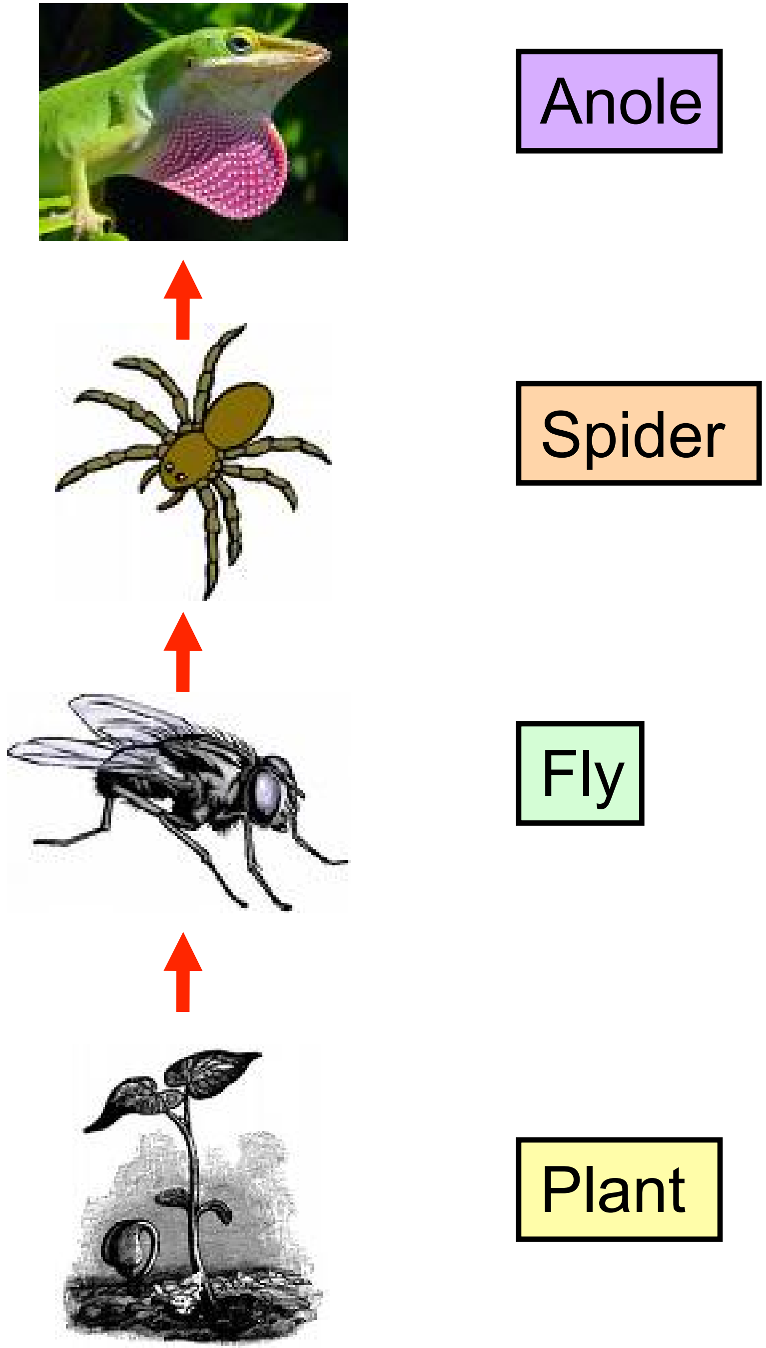
Poison dart frogs
(*Dendrobates*)

Predation

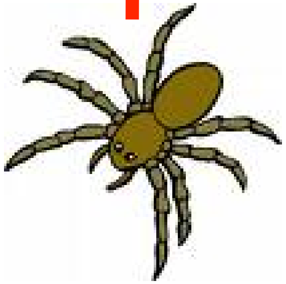
- Why is predation important?
- How can we measure it?
- How do herps avoid predators?
  – Avoid detection
  – Avoid capture
  – Avoid consumption
  – Signal inedibility (or mimic)

Food Chains and Webs

- Food chains and webs graphically describe the feeding relationships within communities
- “Who eats who”

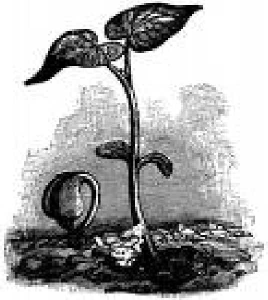

Anole
Spider
Fly
Plant

Anole - tertiary consumer



Spider - secondary consumer

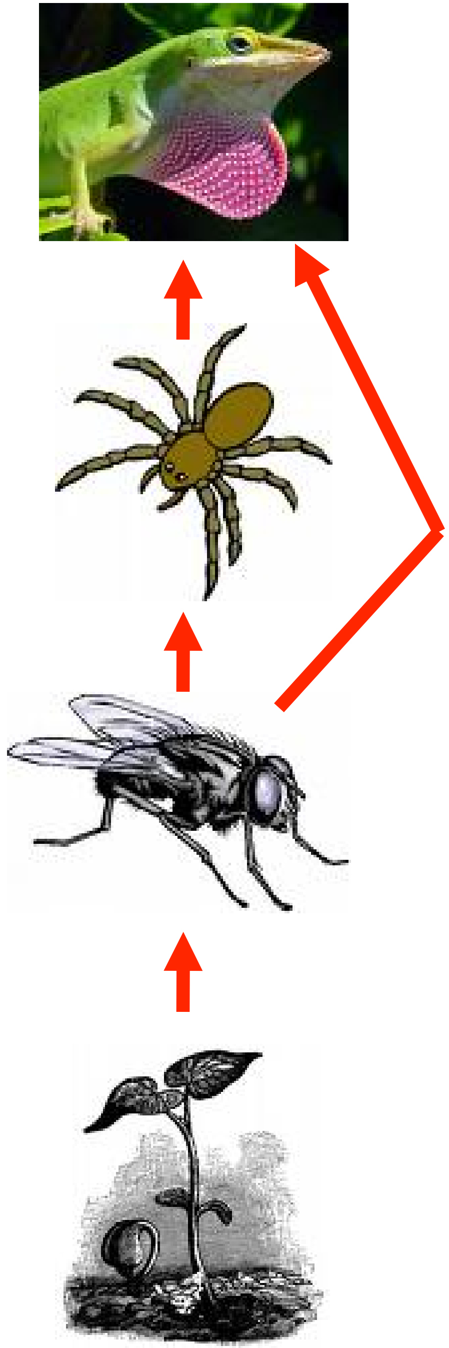
Fly - primary consumer



Plant - producer

Omnivory

- Omnivory is very common in herps
- Many species will eat whatever they can catch
- Some even mix plants and animals
- Diets can vary seasonally, with age, etc.

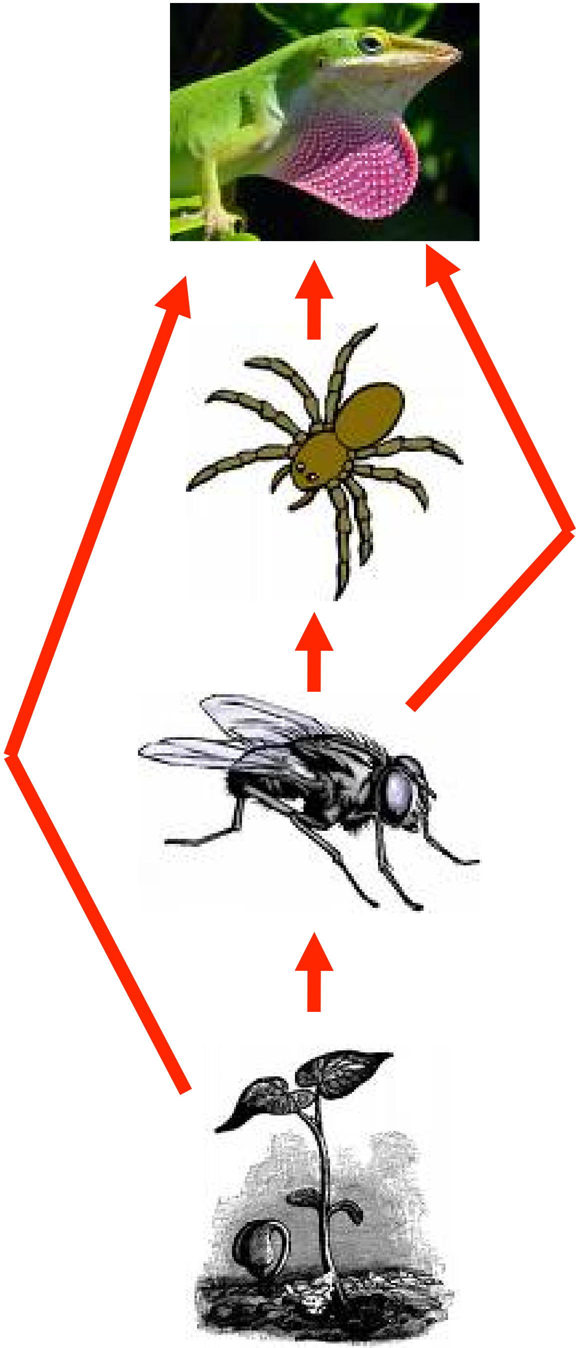


Anole - tertiary consumer

Spider - secondary consumer

Fly - primary consumer

Plant - producer

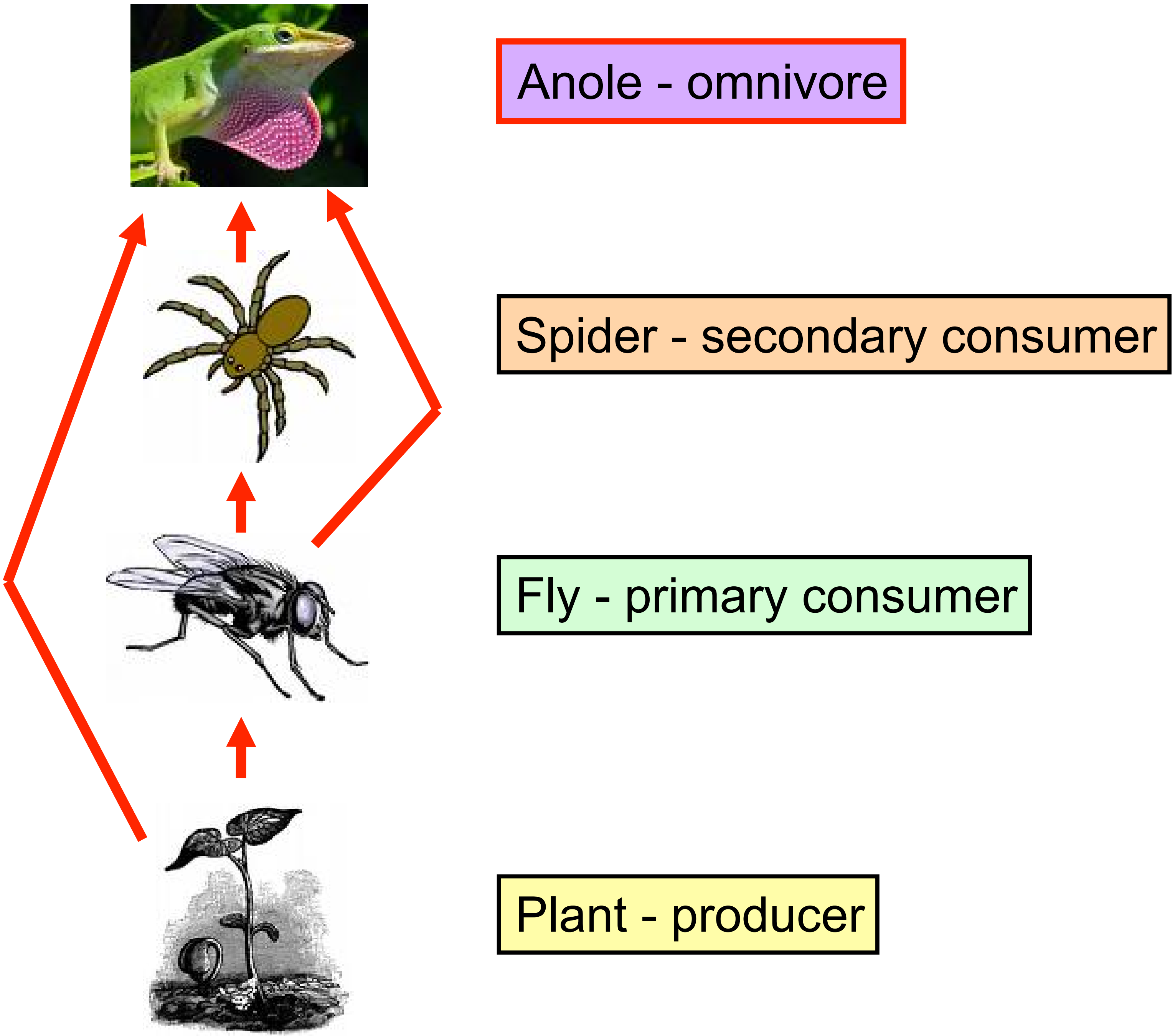


Anole - tertiary consumer

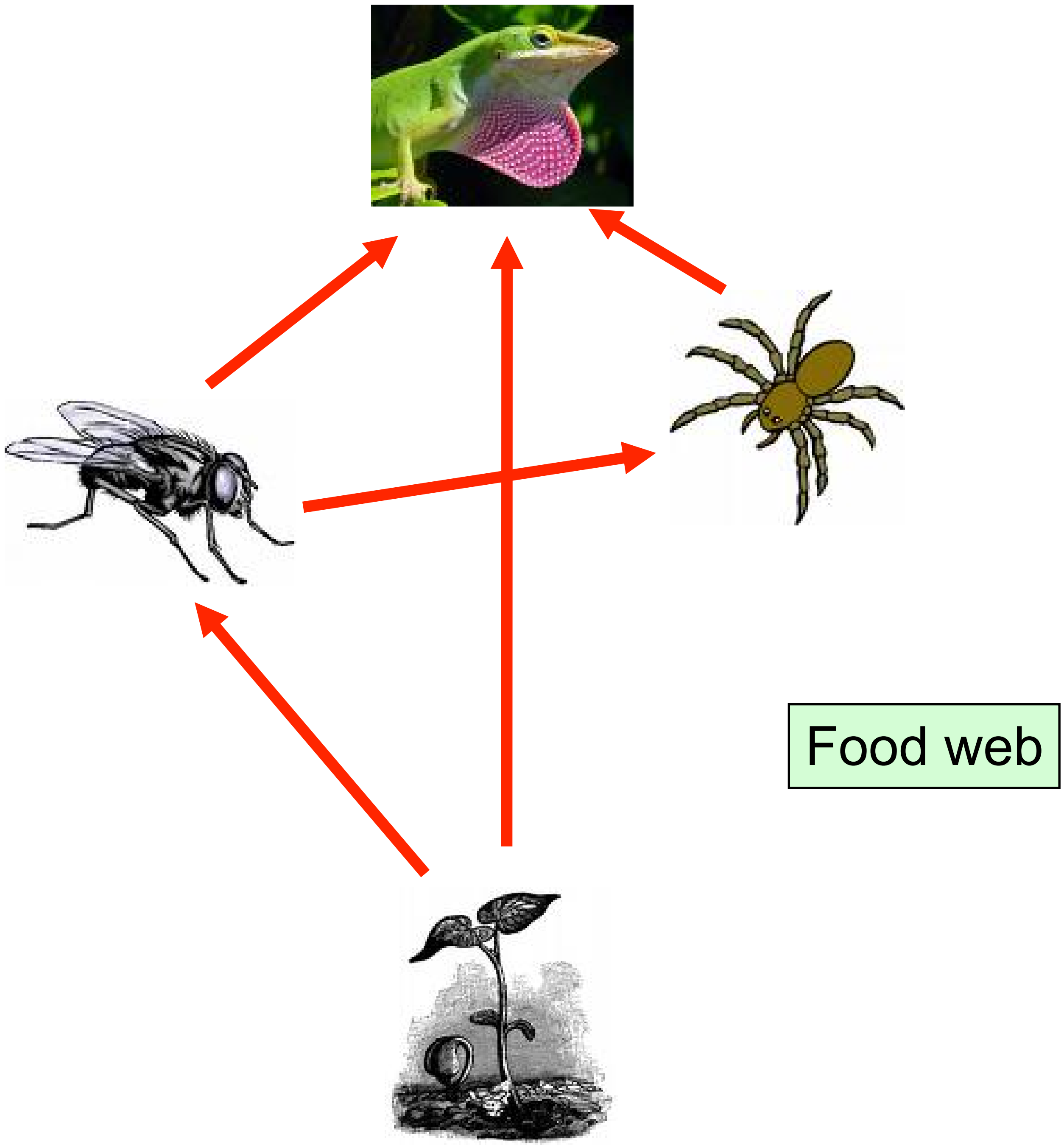
Spider - secondary consumer

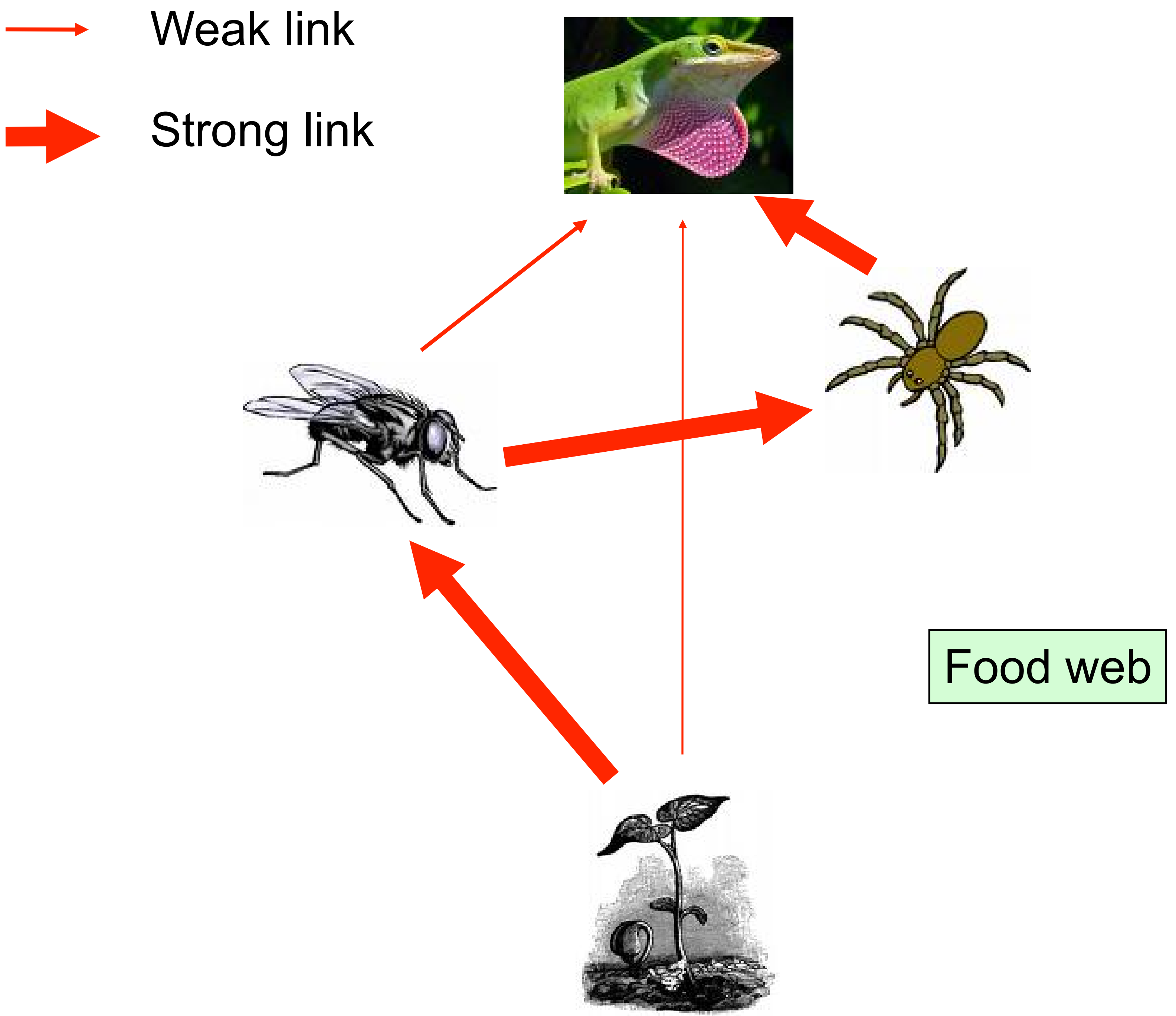
Fly - primary consumer

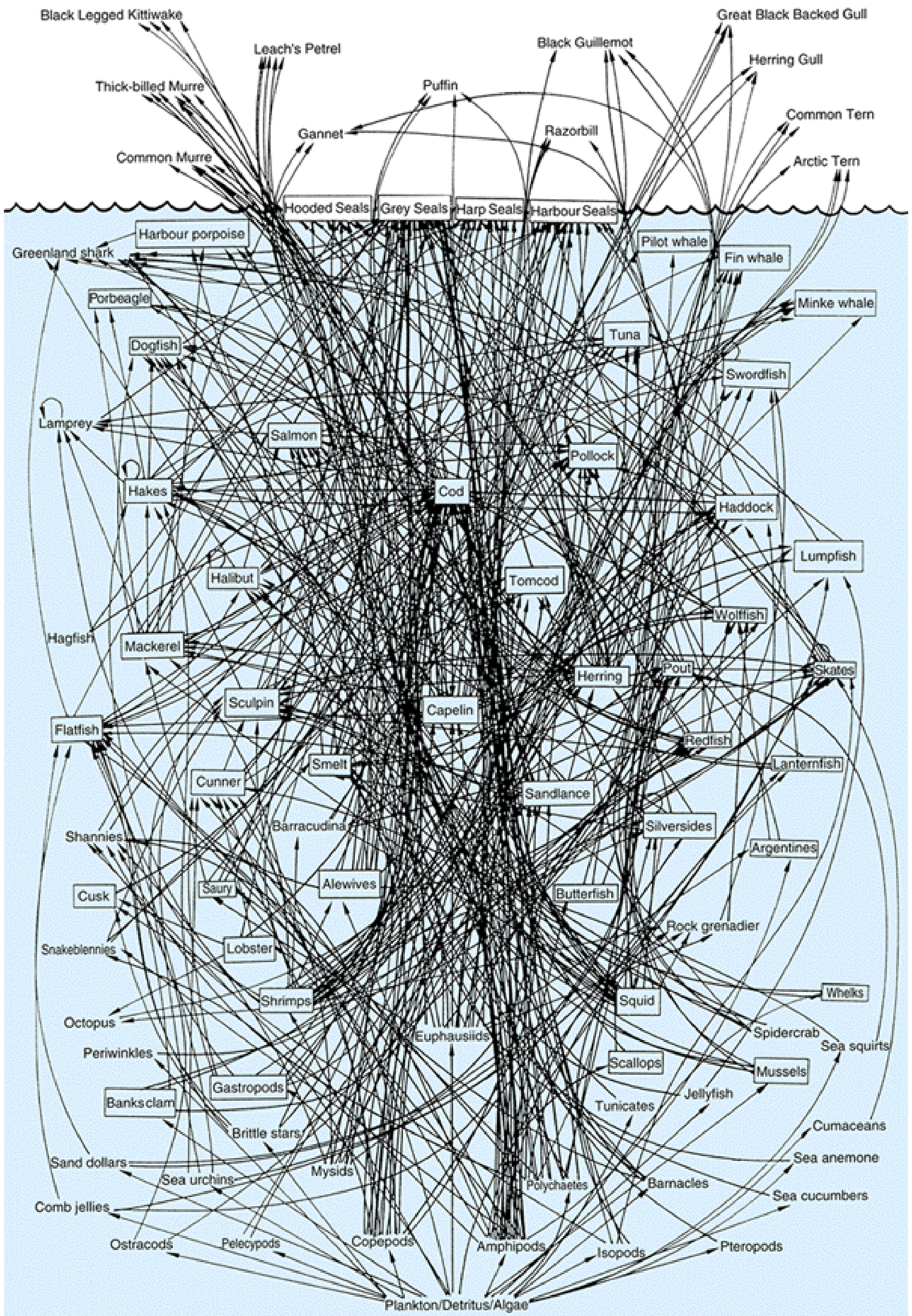
Plant - producer



Anole - omnivore
Spider - secondary consumer
Fly - primary consumer
Plant - producer


Food web


Weak link
Strong link
Food web



A simplified food web for the Northwest Atlantic

Interactions in Food Webs

- Organisms in food webs affect each other
- Changing the abundance of one species is likely to have effects that cascade through the web

Trophic Cascades

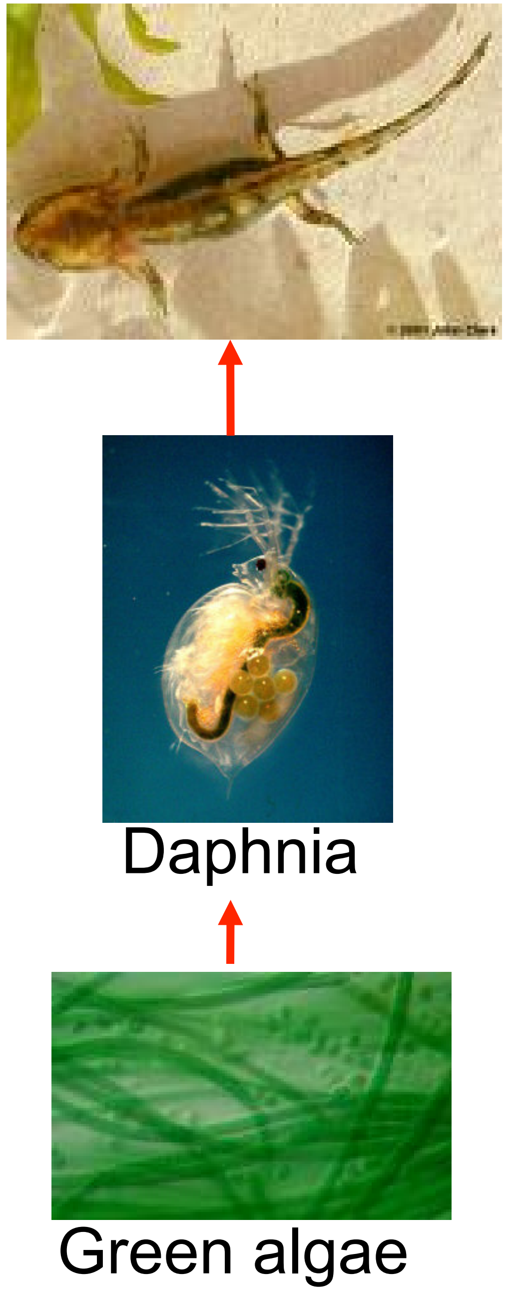
- Species can have effects on other trophic levels
- Example: change the abundance of a species, they eat more food
- This can affect the whole web

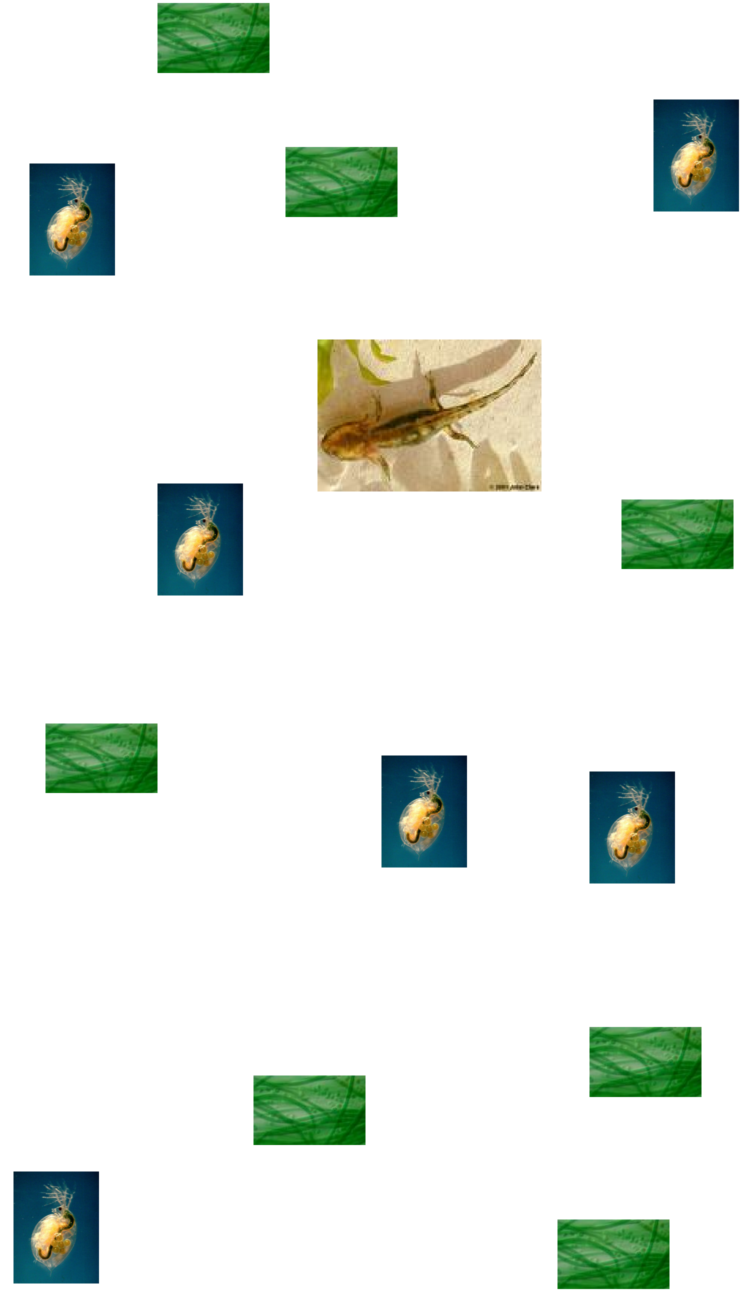
Salamandra salamandra

Daphnia

Green algae

Salamandra salamandra

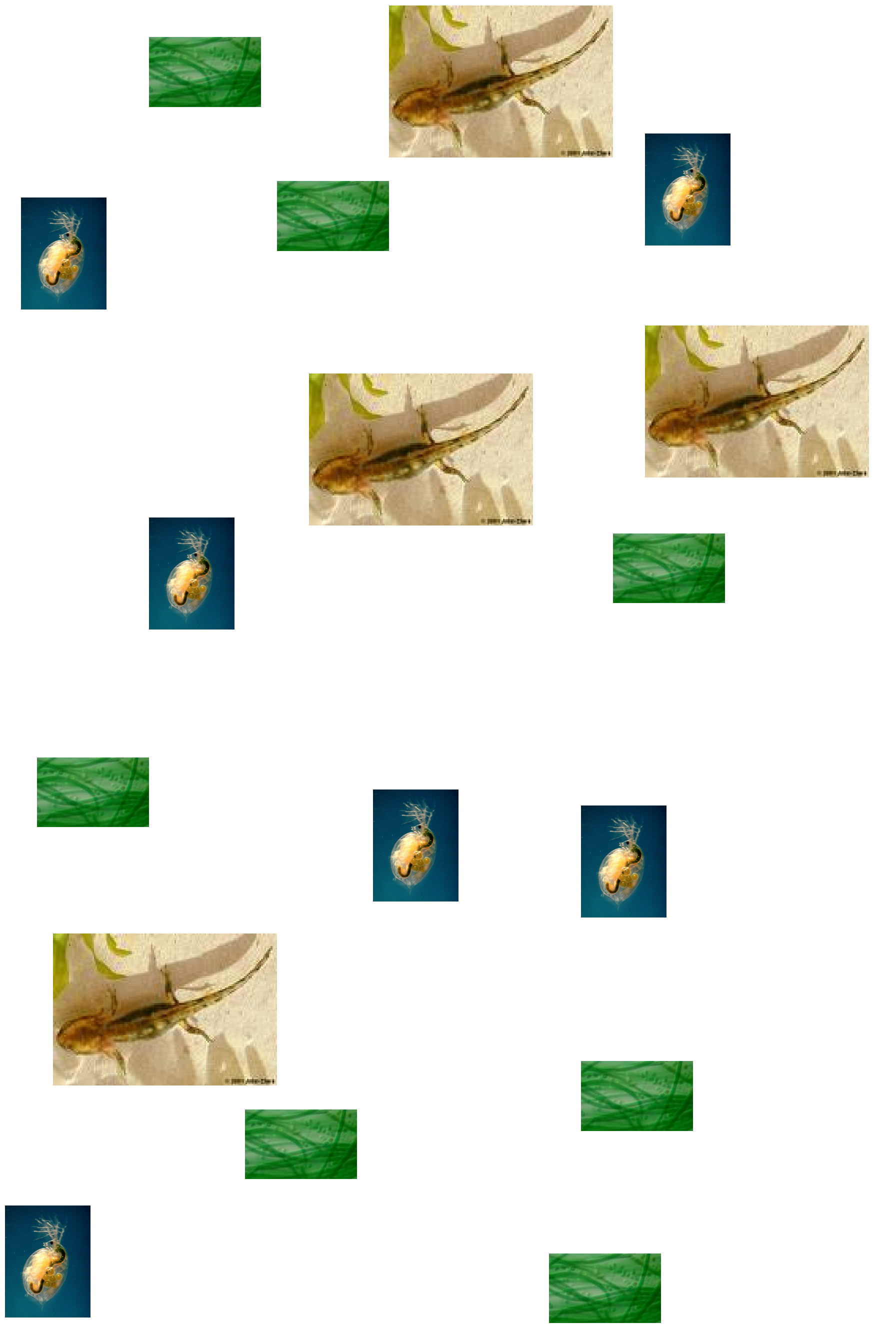




Salamandra salamandra

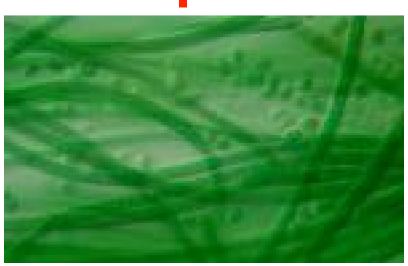
Daphnia

Green algae

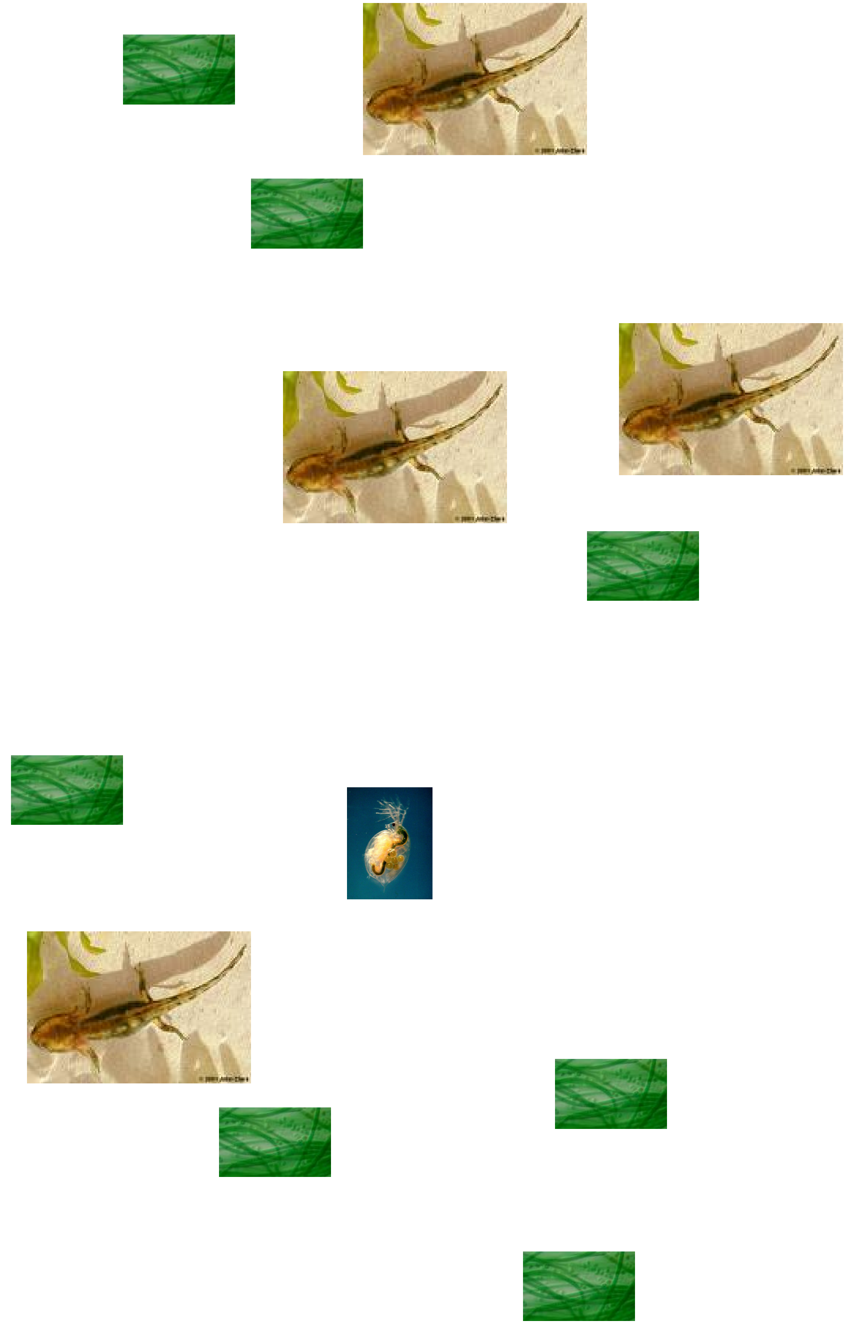


Salamandra salamandra

Daphnia

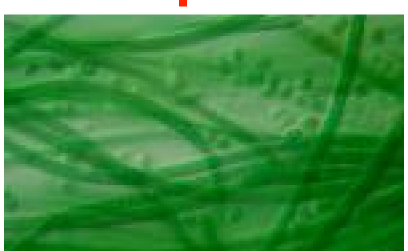


Green algae

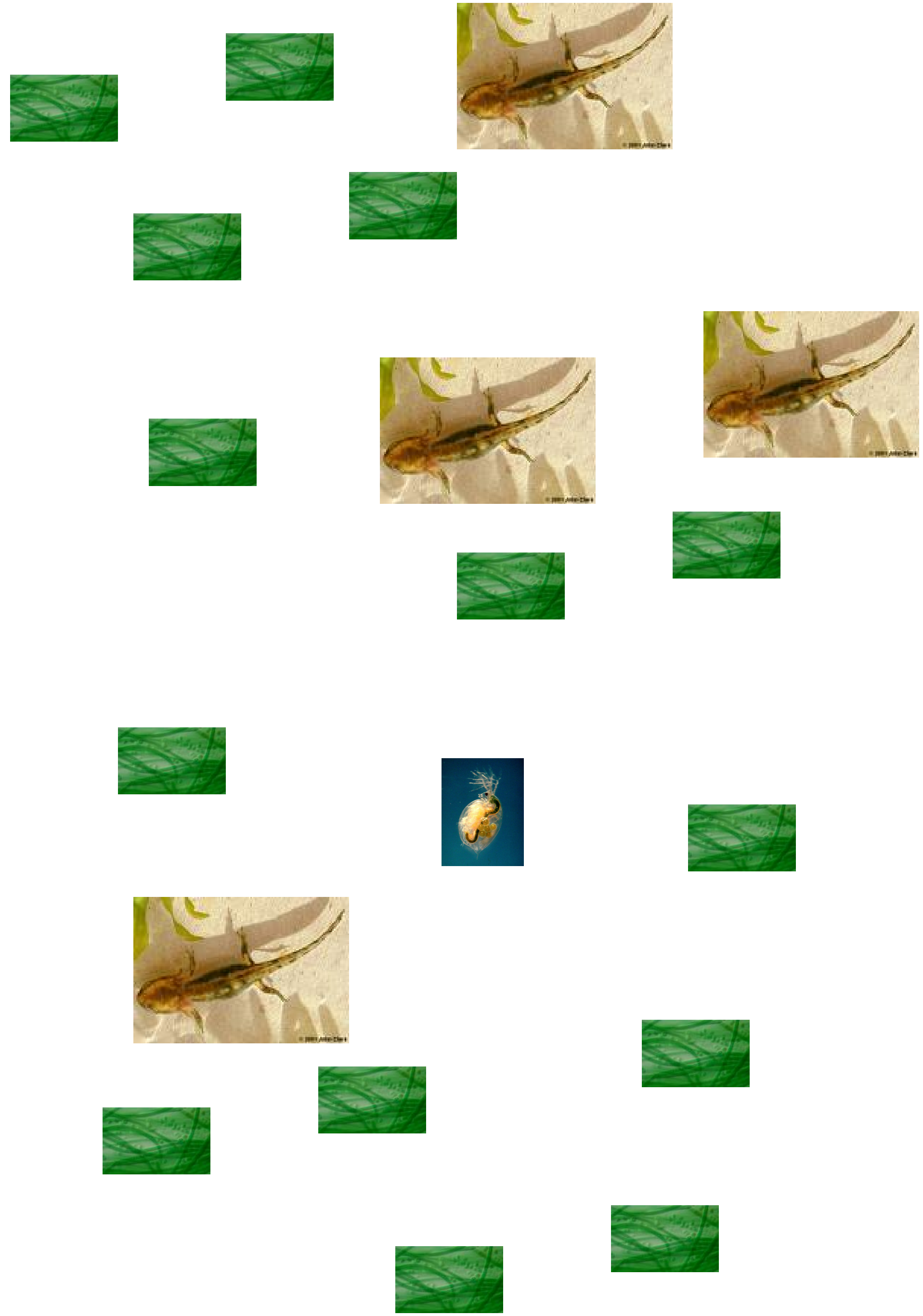


Salamandra salamandra

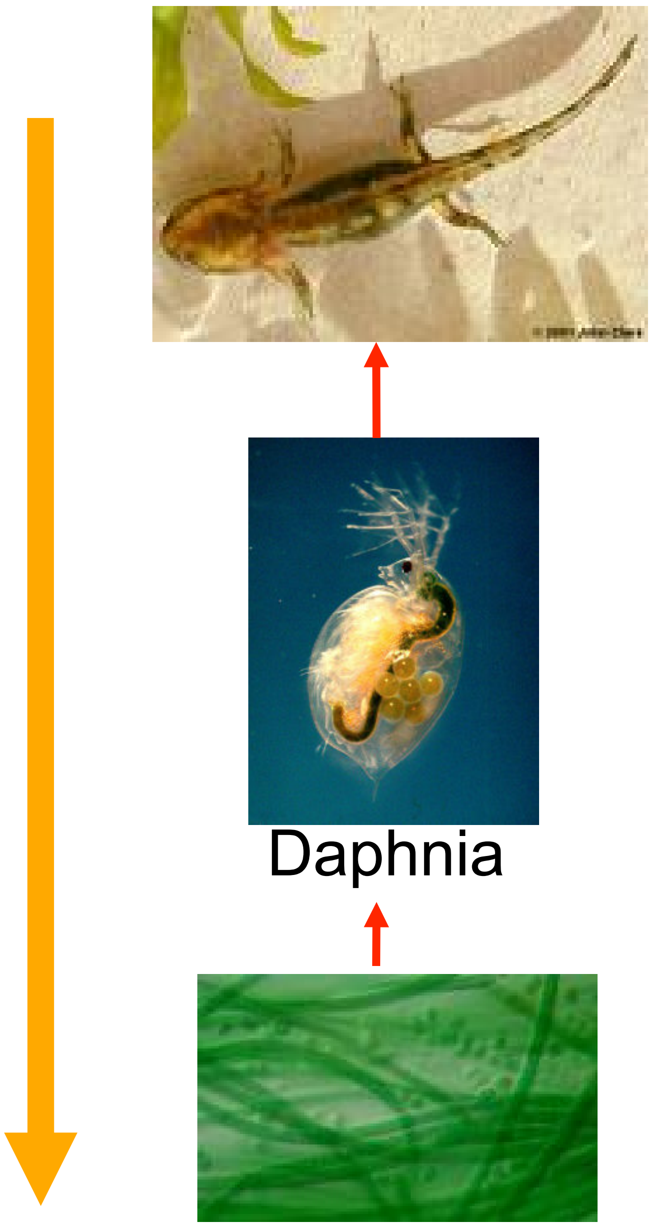
Daphnia



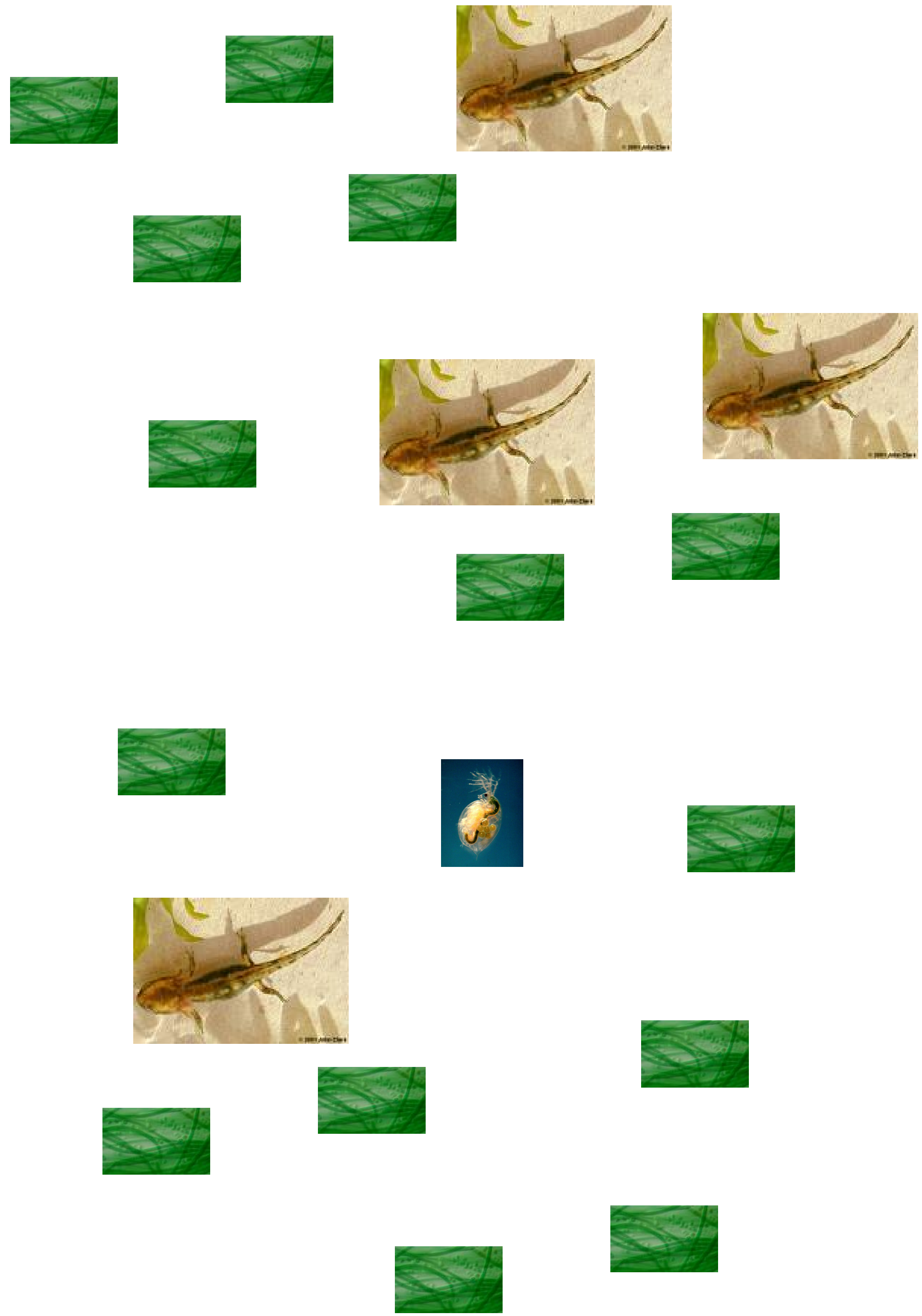
Green algae



Salamandra salamandra

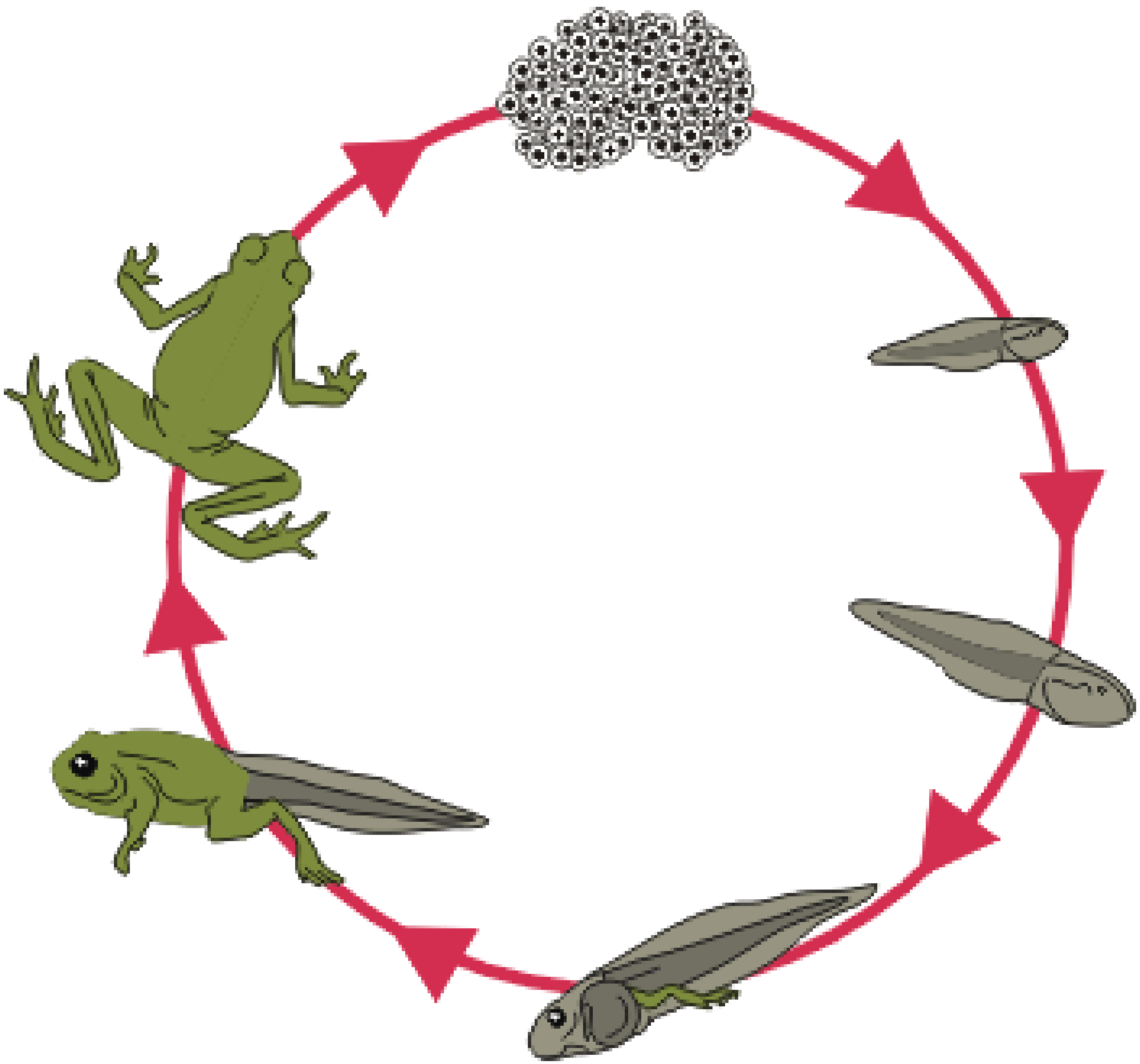


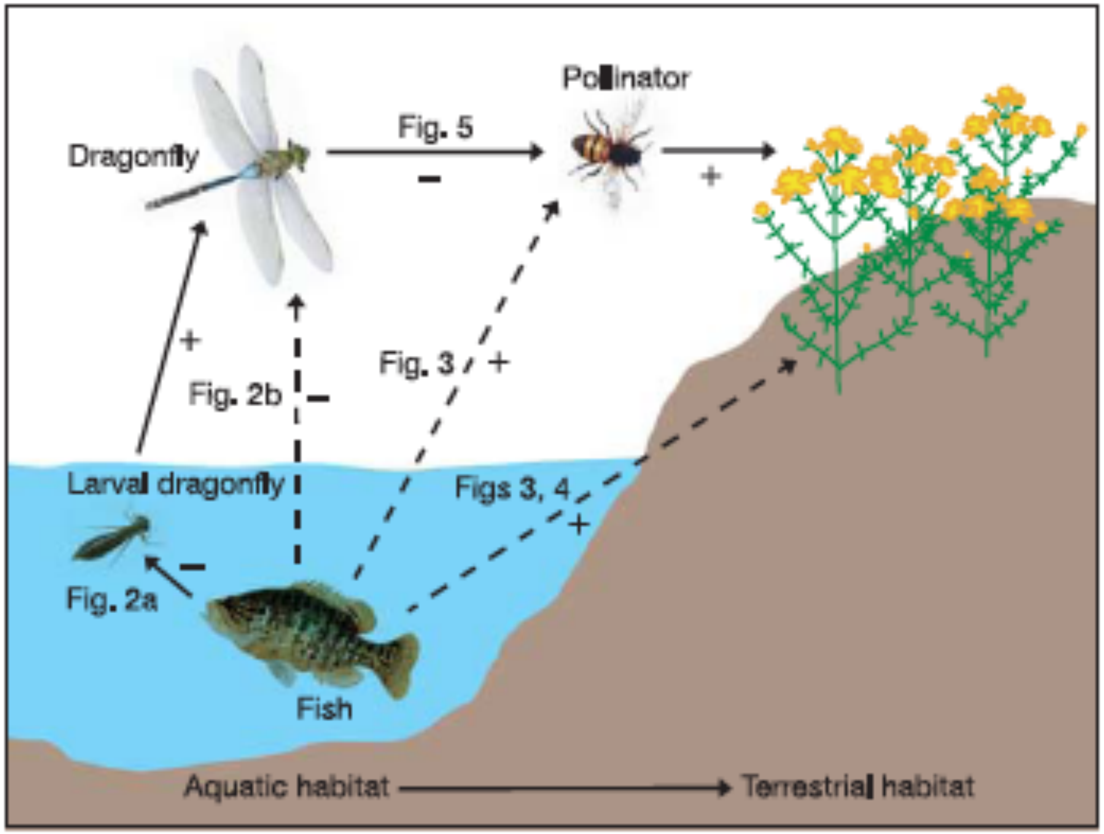
Green algae



Aquatic and Terrestrial

- A trophic cascade is an example of a "top-down" effect
- These effects are more common in aquatic, rather than terrestrial ecosystems
- In terrestrial systems, effects can be either bottom-up or top-down



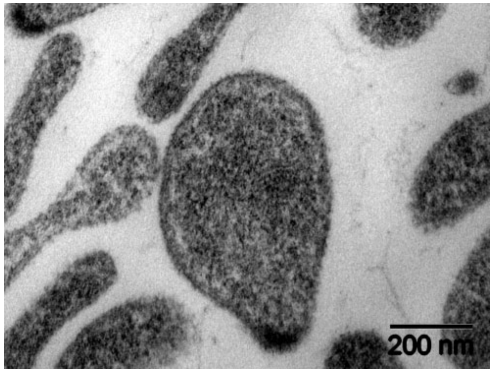


Pollinator
Dragonfly
Fig. 5
+
Fig. 3
+
Fig. 2b
+
Larval dragonfly
Figs 3, 4
+
Fig. 2a
Fish
Aquatic habitat
Terrestrial habitat

Herps and stability

- Herps affect food webs in three ways
  - Omnivory: increase connectedness
  - Energy efficient: increase food chain length
  - Complex life cycles: link different food chains

Disease in Herps



Mycoplasma testudineum

Desert tortoise with URTD

Disease in Herps

- Overview of disease-causing agents
  - Bacteria and viruses
  - Internal parasites
  - External parasites
- Consequences of infection

Disease in Herps

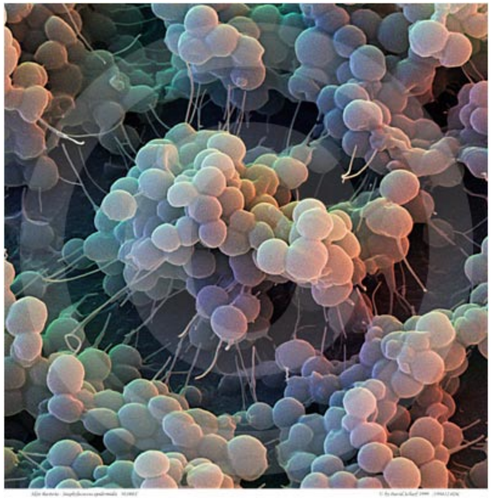
- Overview of disease-causing agents
  - Bacteria and viruses
  - Internal parasites
  - External parasites
- Consequences of infection

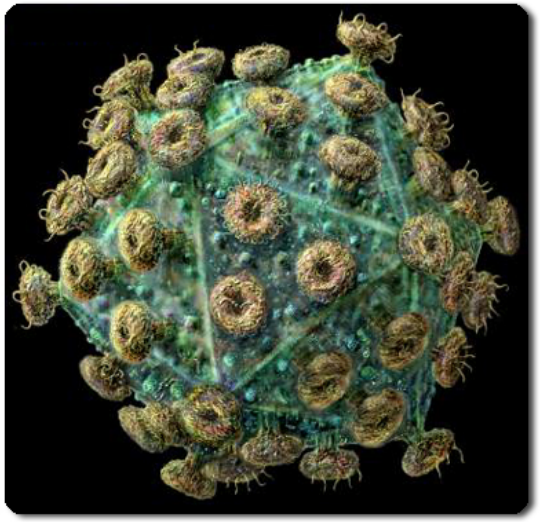
Disease-causing agents

- Extremely common in herps
- Similar to agents in other vertebrates (including humans)
- Three main types
  - Bacteria and viruses
  - Internal parasites
  - External parasites

Bacteria and viruses

- Small, short generation time
- Multiply rapidly, acute effects, high mortality
- Spur immune response





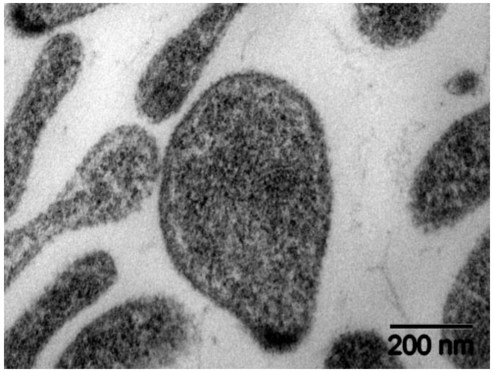
Bacterial Infections

- Red-leg in frogs
- Caused by bacterium *Aeromonas hydophilia*
- May be associated with massive die-offs in the wild

Frog with red-leg disease

Bacterial Infections

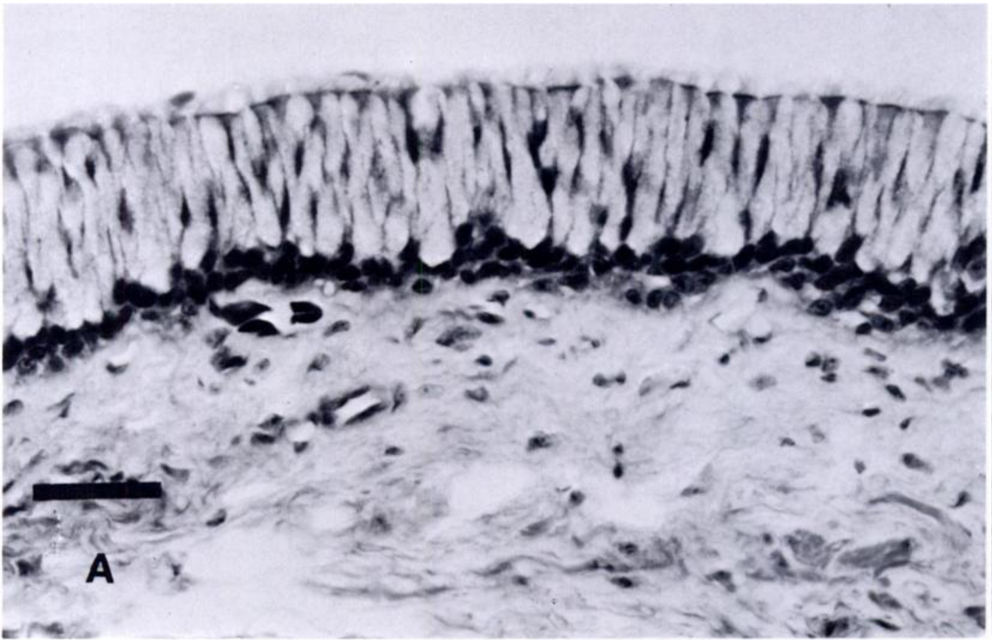
- Upper Respiratory Tract Disease (URTD)
- Found in gopher tortoises, box turtles, and others
- Caused by *Mycoplasma* bacteria (micoplasmosis)



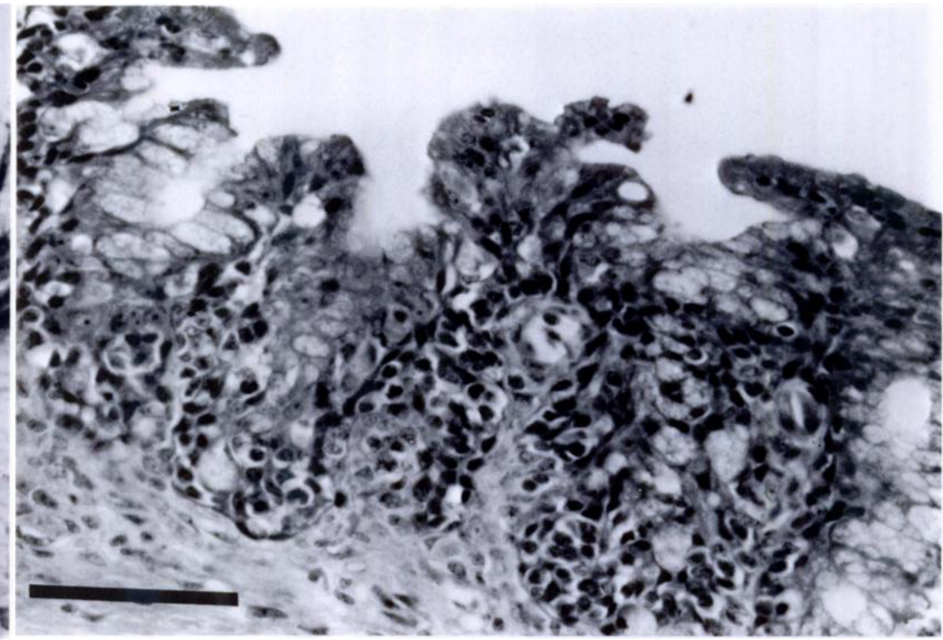
Mycoplasma testudineum

Desert tortoise with URTD

Mycoplasma attacks epithelial cells in the nasal cavity



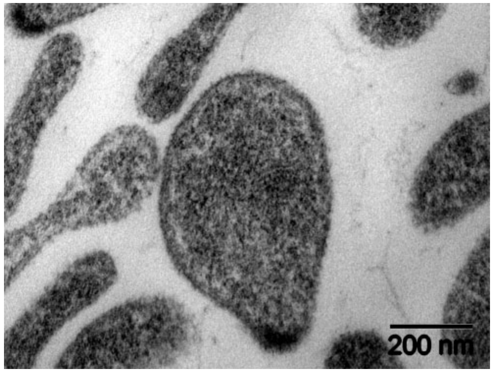
Epithelial cells in nasal cavity
of healthy desert tortoise
(Xerobates agassizii)



Similar cells in a tortoise
with mycoplasmosis

Bacterial Infections

- Upper Respiratory Tract Disease (URTD)
- Found in gopher tortoises, box turtles, and others
- Caused by *Mycoplasma* bacteria (micoplasmosis)
- Common in captive tortoises
- Has been introduced into the wild through translocation of captive individuals



Mycoplasma testudineum

Desert tortoise with URTD

Viral Infections

- Fibropapillomatosis in sea turtles
- Causes neoplasias (tumors) to grow on skin
- Caused by herpes-like virus

Green Turtle with fibropapillomatosis (*Chelonia mydas*)

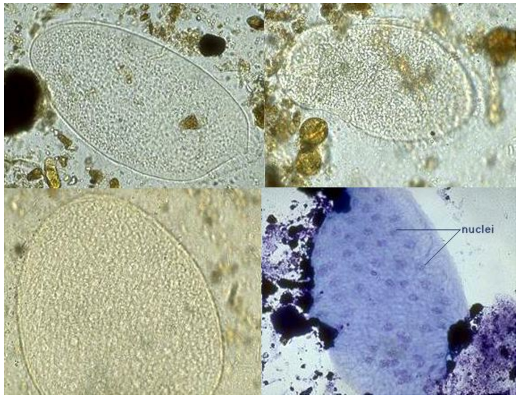
Viral Infections

- Fibropapillomatosis in sea turtles
- Causes neoplasias (tumors) to grow on skin
- Caused by herpes-like virus
- Associated with human population centers

Green Turtle with fibropapillomatosis (*Chelonia mydas*)

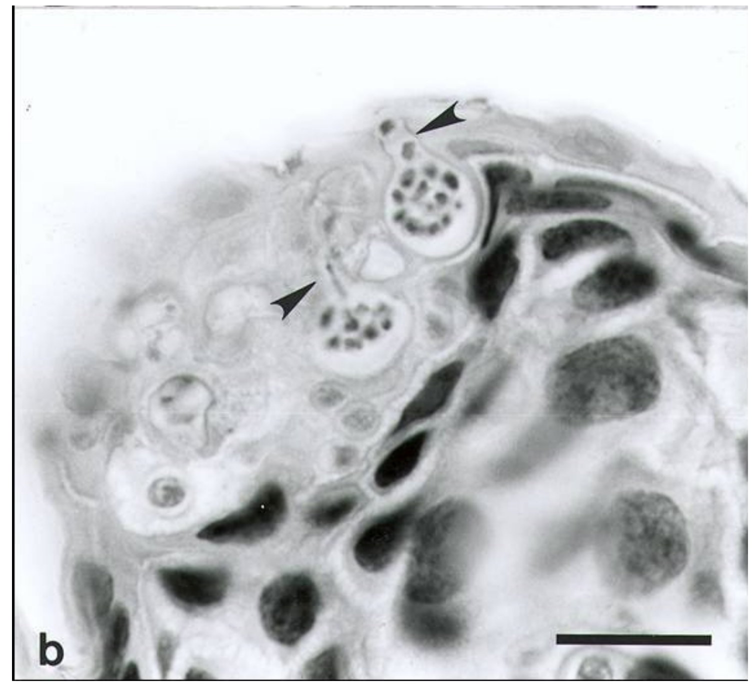
Internal Parasites

- Fungi
- Protozoans
  - Trypanosomes, amoeba, ciliates, coccidians, *plasmodium* (malaria)
  - Blood, organs
- Metazoans
  - “worms”
  - Flatworms, tapeworms, flukes, roundworms, thorny-headed worms, lungworms



Fungal Parasites

- Chytrid fungus (*Batrachochytrium dendrobatidis*) causes chytridiomycosis
- Infects the skin of frogs
- Contributing to worldwide amphibian decline

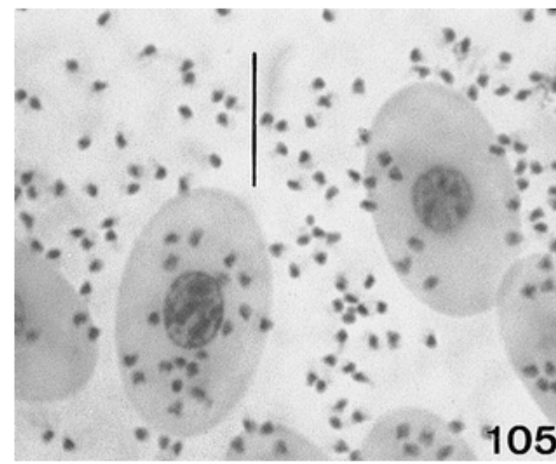


Berger et al. 1995

Internal Protozoan Parasites

- *Plasmodium* (malaria)
- Over 60 species infect reptiles (and more are being added)

Egernia stokesii



Plasmodium mackerrasae in the blood of *E. stokesi*

(Telford Jr and Stein 2000)

Plasmodium mexicanum infects *Sceloporus occidentalis*

Western fence lizard
Sceloporus occidentalis

Sandfly
Luzomyia vexator

Fialho and Schall 1995

Eisen and Wright 2000

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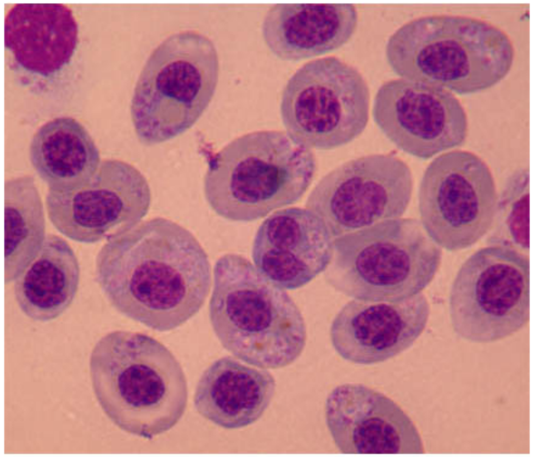

Massive infection of red blood cells in a lizard

Fialho and Schall 1995

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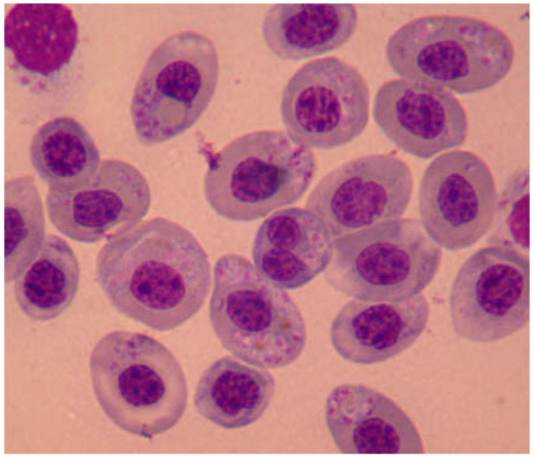
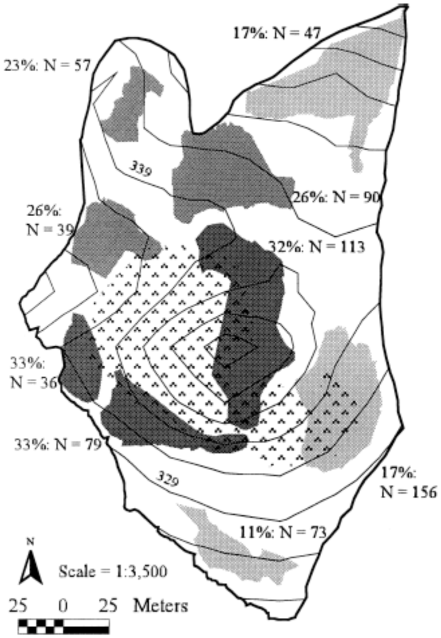


Massive infection of red blood cells in a lizard



Infection prevalence in one area of California

Fialho and Schall 1995

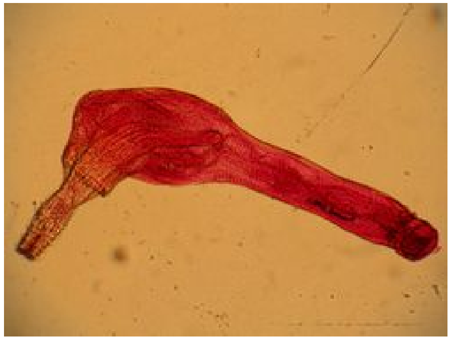
Eisen and Wright 2000

Internal Metazoan Parasites

- Intestinal “worms” very common in herps
- Flatworms, tapeworms, roundworms, etc.
- Taxonomically diverse
- Some general, some species-specific

Internal Metazoan Parasites

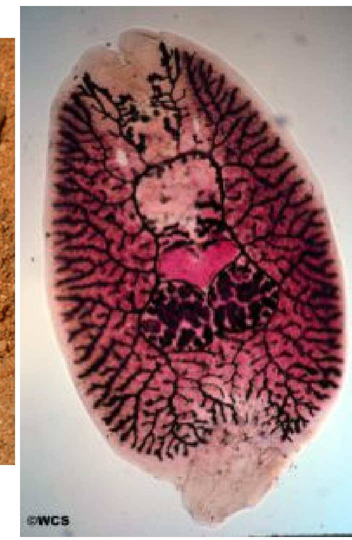
- Intestinal “worms” very common in herps
- Flatworms, tapeworms, roundworms, etc.
- Taxonomically diverse
- Some general, some species-specific
- Example: thorny-headed worms (Acanthocephala)
  - Intestinal parasite with no guts
  - Absorbs nutrients directly



Internal Metazoan Parasites

- Monogeaen flukes in spadefoot toads
- Flatworms that live in the bladder

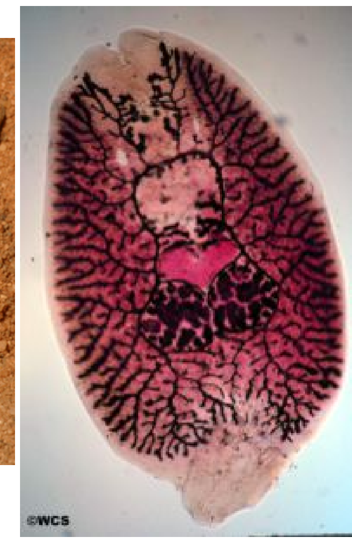
Scaphiopus couchii



Internal Metazoan Parasites

- Monogeaen flukes in spadefoot toads
- Flatworms that live in the bladder
- Infective only 1-3 days per year, when the toads enter temporary pools to breed
- Released into water
- Flukes enter nostrils of other toads, migrate to bladder

Scaphiopus couchii



Internal Parasite Life Cycle

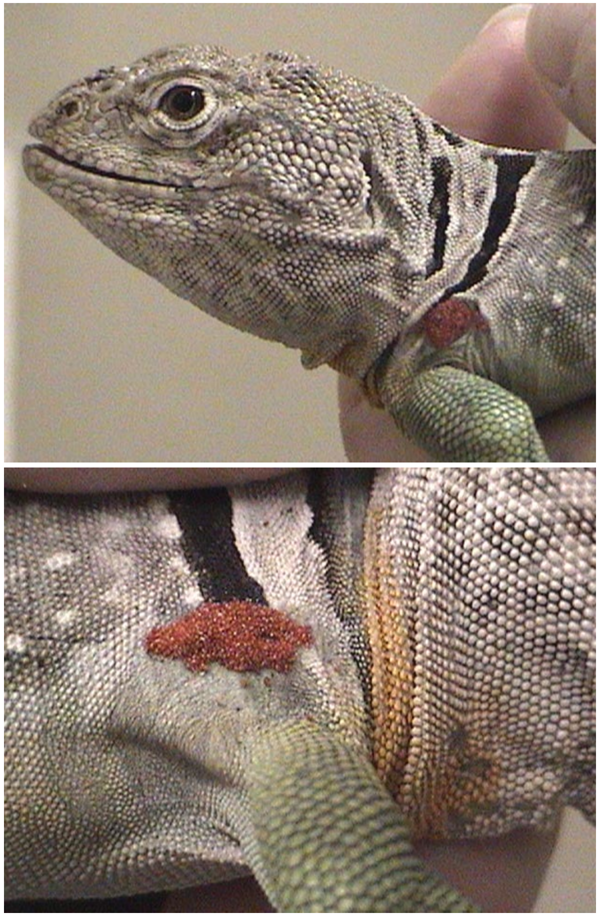
- Many parasites have more than one host
- Different life stages might have different hosts
- Example: intermediate hosts in flukes

External parasites

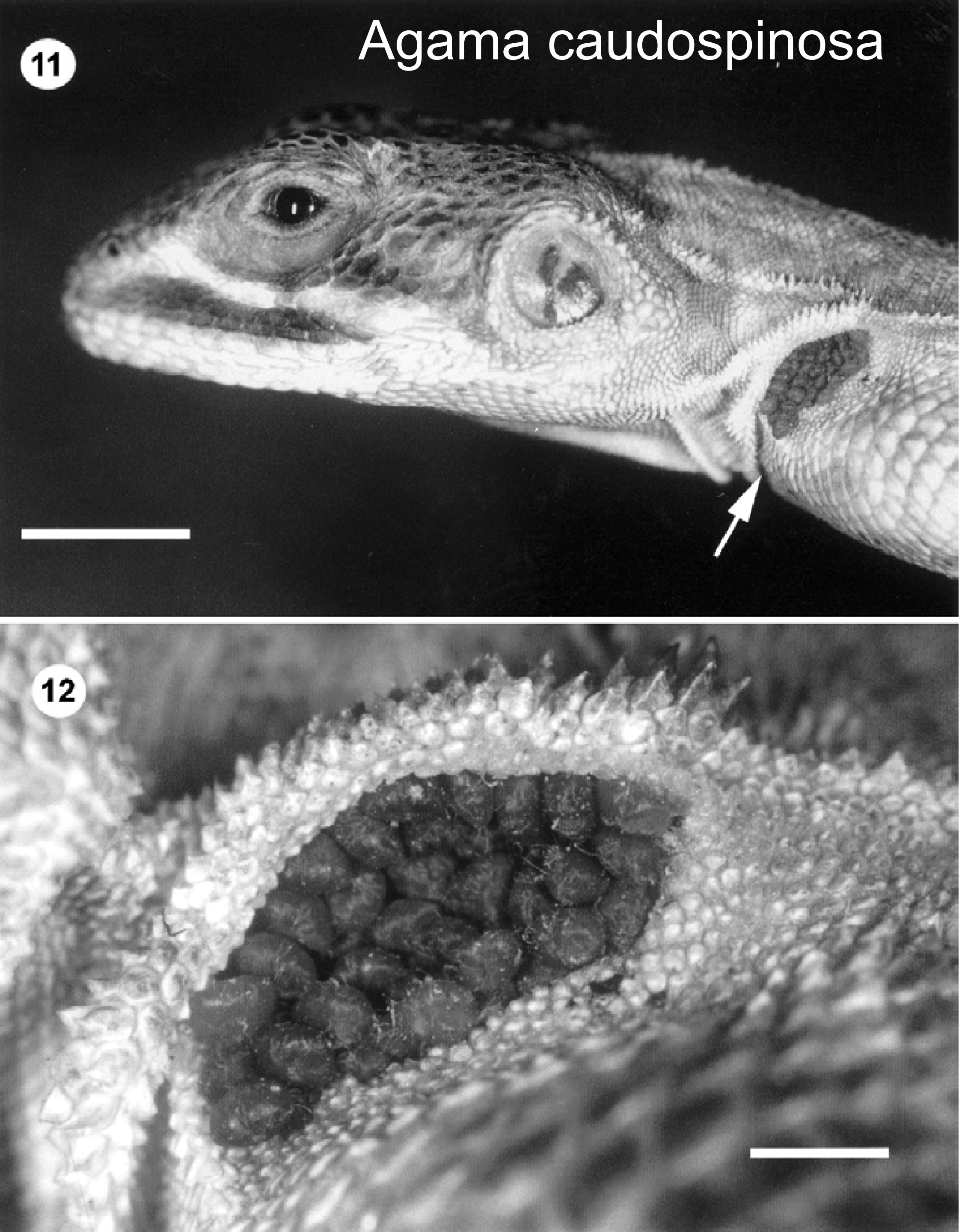
- Also very common in herps
- Include mites, ticks, leeches (attached)
- Also mosquitos and other flies
- Spend at least part of their life cycle separate from the host

External Parasites

- Trombiculid mite larvae
- Small red “chiggers” on the skin
- Feed on skin cells



Mites *(Eutrombicula)* on a collared lizard



Mite Pockets

- Some species have skin folds full of mites
- Their function, if they have one, is unknown

Bertrand and Modry 2004

Other external parasites

Ticks

Leeches

Mosquitos

Disease in Herps

- Overview of disease-causing agents
  - Bacteria and viruses
  - Internal parasites
  - External parasites
- Consequences of infection

Consequences of infection

- Effects on individual traits and fitness
- Effects on communities
- Disease outbreaks in wild herps

Takydromus tachydromoides

Consequences of infection

- Effects on individual traits and fitness
- Effects on communities
- Disease outbreaks in wild herps

Takydromus tachydromoides

Total Parasite Load

At one locality in Japan:

- 8 species of worms
- 6 species of intestinal protozoans
- 5 species of blood parasites
- Tick
- Bacteria + virus

Takydromus tachydromoides

How do herps fight infection?

- Immune system
- Similar to other tetrapods, including humans
  - Barriers: skin, antibacterial mucous
  - Adaptive immunity (T-cells, lymphocytes)
  - Physiology (“fevers”, etc.)

Consequences of infection

- Can range from no effect to death
- Strong effects have been shown
  - Anemia
  - Slower movement
  - Reduced performance
  - Lower fitness
- Ectoparasites can lead to endoparasites

Malaria in *Sceloporus*

	Group		
	Infected	Noninfected	P
Hematological parameters			
iRBC (percent)	9.5 (7.3; 68)	2.6 (4.1; 25)	$\ll .001$
Hemoglobin (g per 100 ml of blood)	5.5 (1.3; 27)	7.3 (1.4; 22)	$<.001$
Hematocrit (percent)	33.4 (6.5; 17)	32.3 (5.1; 21)	$>.25$
RBC ($\times 10^3$ per mm^3 of blood)	972.1 (245.1; 12)	843.4 (251.2; 15)	$>.05$
Oxygen consumption [ml/(g.h)]			
Resting	0.59 (.105; 14)	0.54 (.131; 15)	$>.10$
Active	1.30 (.252; 14)	1.53 (.351; 14)	$<.05$
Aerobic scope	.71 (.247; 14)	1.00 (.336; 14)	$<.01$
Behavioral performance			
Burst speed (m/sec)	1.28 (.41; 15)	1.44 (.38; 15)	$=.1$
Running stamina*	17.0 (3.68; 14)	21.3 (5.82; 15)	$<.01$
Running stamina†	26.9 (6.81; 15)	32.2 (8.1; 15)	$<.05$

*Meters run in 30 seconds. †Meters run in 2 minutes.

Total Parasite Load

At one locality in Japan:

- 8 species of worms
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- Tick
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Takydromus tachydromoides

Total Parasite Load

At one loca

- 8 species
- 6 species protozoar
- 5 species parasites
- Tick
- Bacteria + virus

No effect on any measured characters

mus tachydromoides

Consequences of infection

- Effects on individual traits and fitness
- Effects on communities
- Disease outbreaks in wild herps

Takydromus tachydromoides

Parasites in Communities

- Parasites can affect the interactions between species in communities
- Another niche axis to partition
  - "Parasite-mediated competition"
- Can alter host behavior

Parasites in Anole Communities

- Two species of anole on St. Maartin
- *A. gingivinus*

- *A. wattsi*

Parasites in Anole Communities

- Two species of anole on St. Maartin
- *A. gingivinus*
  - Superior competitor
  - Susceptable to malaria
- *A. wattsi*
  - Inferior competitor
  - Rarely infected with malaria

Consequences of infection

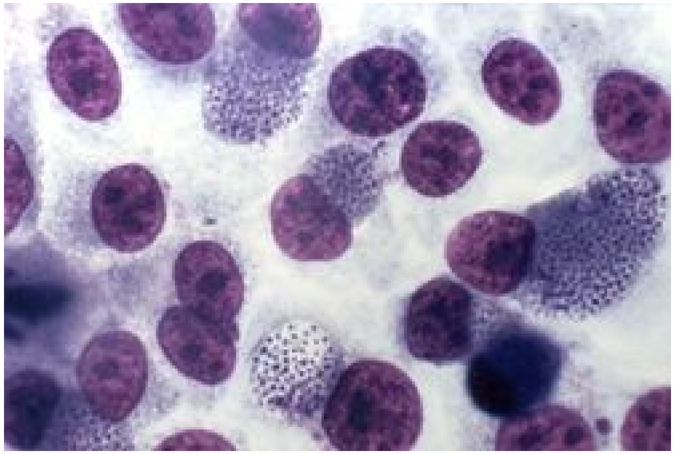
- Effects on individual traits and fitness
- Effects on communities
- Disease outbreaks in wild herps

Takydromus tachydromoides

Disease Outbreaks

- Microsporidians
- Related to fungi
- Infect muscles of frogs
- Implicated in die-off of *Bufo bufo* in the 1960s

Bufo bufo



Microsporidia

Disease Outbreaks

- Red-leg in frogs
- Caused by bacterium *Aeromonas hydophilia*
- Sometimes see outbreaks

Frog with red-leg disease

Examples of disease and decline/ extinction

Table 2 Empirical examples of mechanisms of disease-induced extinction

Mechanism	Species	Impact	Reference
Small populations/ stochasticity	Tree snail (*Partula turgida*)	Extinction	Daszak & Cunningham (1999)
	Thylacine (*Thylacinus cynocephalus*)	Possible extinction	Guiler (1961) (in McCallum & Dobson 1995)
	Golden toad (*Bufo periglenes*)	Probable extinction	Pounds *et al.* (1997)
	Black-footed ferret (*Mustela nigripes*)	Probable extinction	Thorne & Williams (1988)
	Mednyi arctic fox (*Alopex lagopus semenovi*)	Probable extinction	Goltsman *et al.* (1996)
	African wild dog (*Lycaon pictus*)	Population crash	Burrows *et al.* (1994)
	Boreal toad (*Bufo boreas*)	Population crash	Muths *et al.* (2003)
	Noble crayfish (*Astacus astacus*)	Population crash	Taugbol *et al.* (1993)
	Spanish Ibex (*Capra pyrenaica hispanica*)	Population crash	Fandos (1991), Leon-Vizcaino *et al.* (1999)
	Big-horn sheep (*Ovis canadiensis*)	Population crash (model)	Gross *et al.* (2000)
	Florida torreya (*Torreya taxifolia*)	Population crash and predicted extinction (model)	Schwartz *et al.* (1995, 2000)
Reduced genetic variability	Pocket gopher (*Thomomys bottae*)	Increased susceptibility to disease	Sanjayan *et al.* (1996)
	Wolves on Isle Royale (*Canis lupis*)	Increased susceptibility to disease	Peterson *et al.* (1998)
	Cheetahs (*Acinonyx jubatus*)	Increased susceptibility to disease	O'Brien *et al.* (1985)
Non-density dependent transmission	Koala/Chlamydia	Possible population crash (model)	Augustine (1998)
	Eupatorium makinoi Asteraceae	Population crash	Funayama *et al.* (2001)
Inhomogeneous mixing	Rabbit/Rabbit haemorrhagic disease	Possible population crash (model)	White *et al.* (2003)
	Common flax (*Linum marginale*)	Possible population crash (model)	Thrall *et al.* (2003)
Biotic reservoir	Iiwi (*Vestiaria coccinea*)	Population crash	Atkinson *et al.* (1995)
	Amakihi (*Hemignathus virens*)	Population crash	Atkinson *et al.* (2000)
	White-tailed deer (*Odocoileus virginianus*)/ moose (*Alces alces*)	Population reduction	Schmitz & Nudds (1994)
	Red squirrel (*Sciurus vulgaris*)	Population reduction	Rushton *et al.* (2000)
	Ethiopian wolf (*Canis simensis*)	Population reduction (model)	Haydon *et al.* (2002)
Abiotic reservoir	Tussock moth (*Orgya antiqua*)	Population crash	Richards *et al.* (1999)
Indirect extinction	Eelgrass limpet (*Lottia alveus*)	Extinction	Carlton *et al.* (1991)
	Eagle owl (*Bubo bubo*)	Population crash	Martinez & Zuberogoitia (2001)

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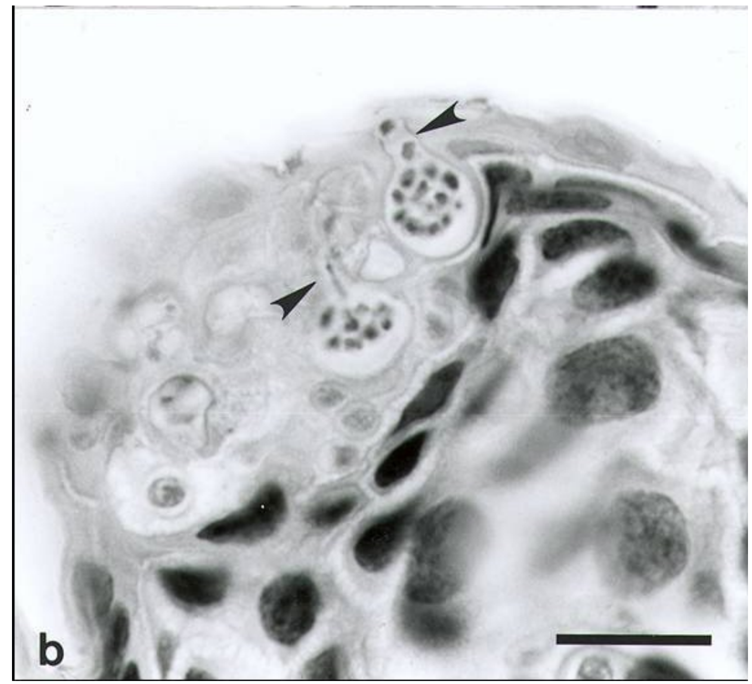
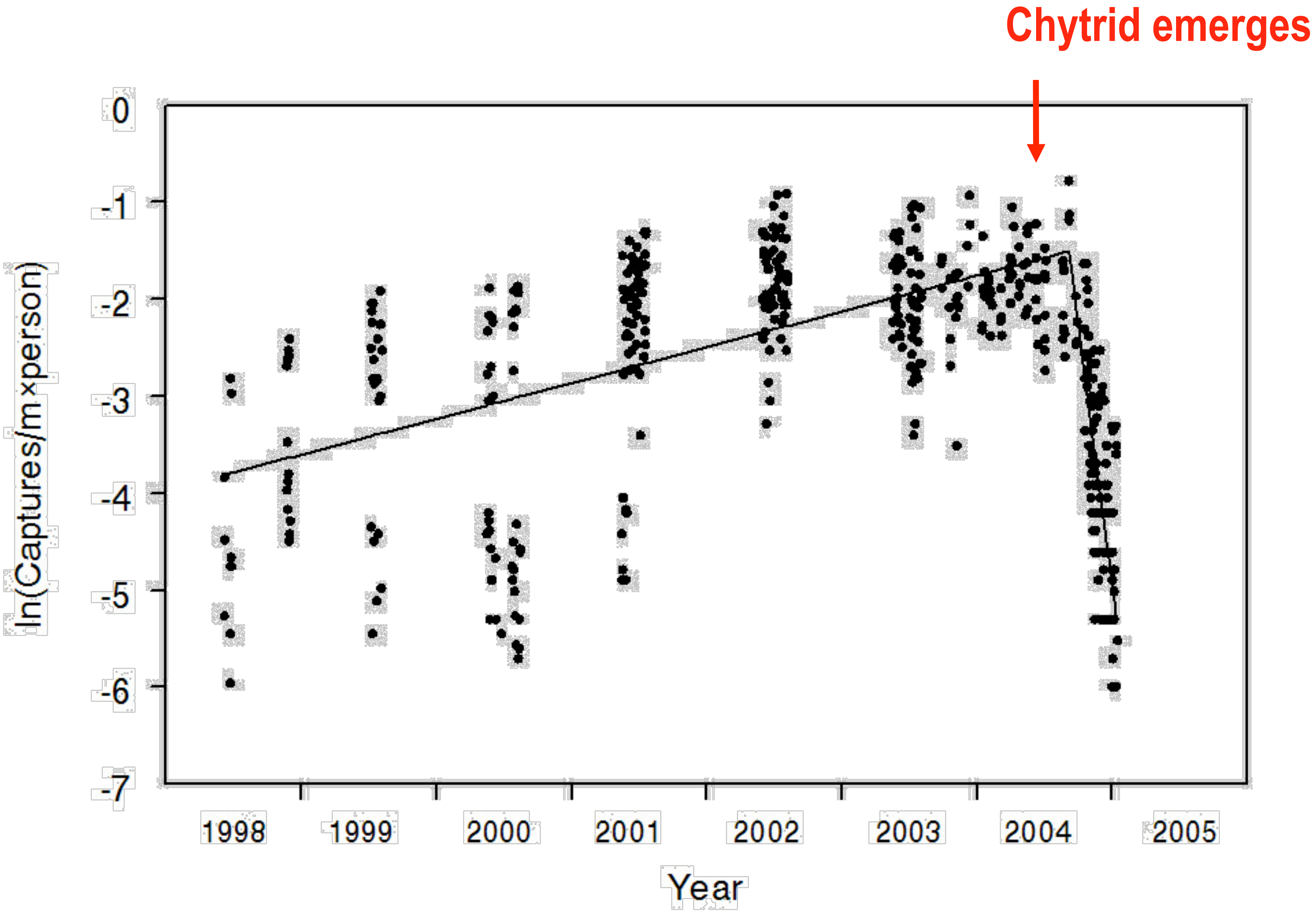
Disease Outbreaks

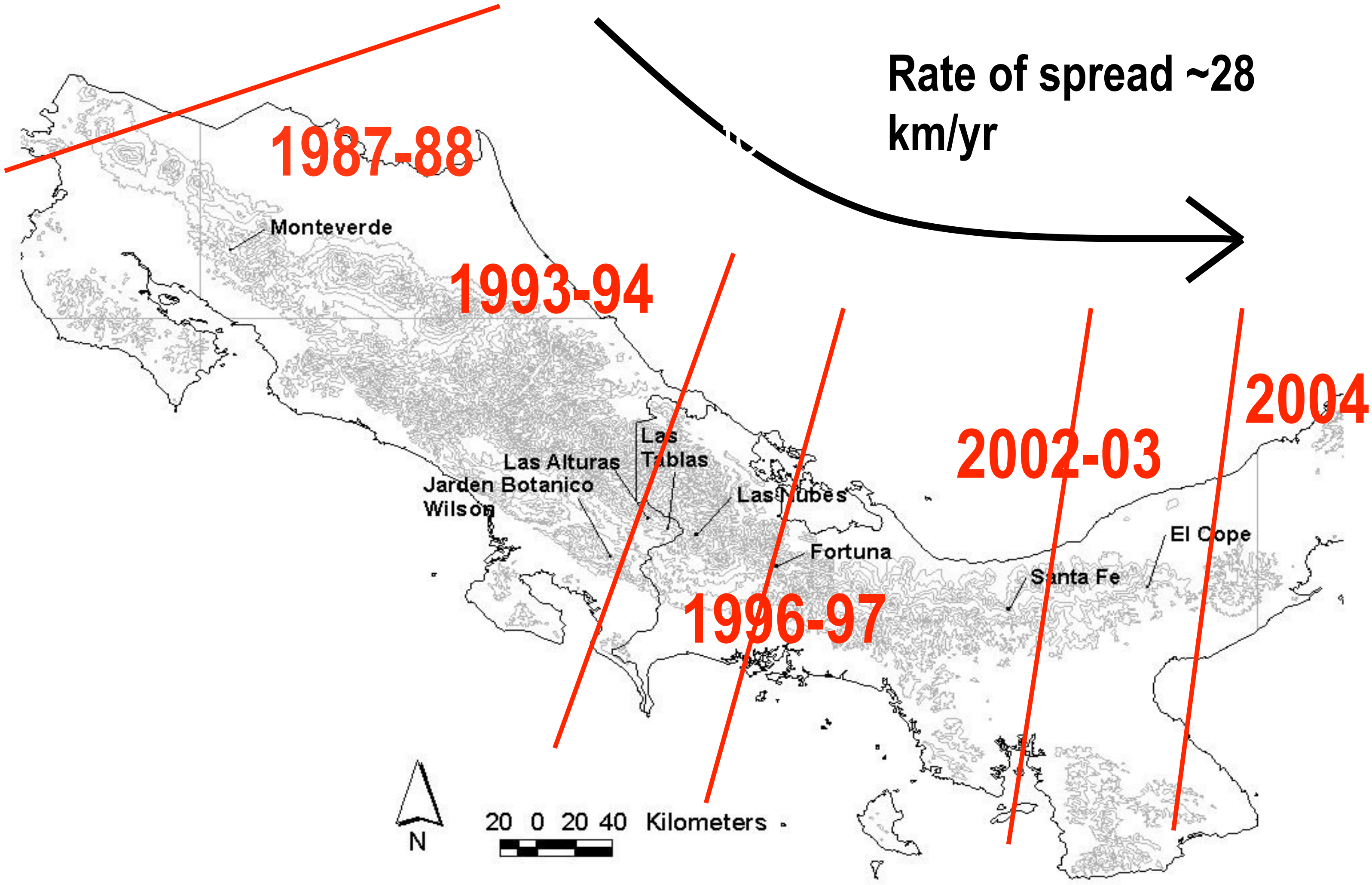
- Chytrid fungus
- Associated with massive die-offs of amphibians world-wide
- Interacts with other environmental factors (UV, temperature)
- To be continued…



Amphibian density changes along streams



Spread of Chytrid



Source: Lips et al. 2006, PNAS.

Emerging infectious diseases: A leading threat to public and wildlife heath

Emerging infectious diseases: A leading threat to public and wildlife heath

Why do diseases (such as chytrid) “emerge”?

Emerging infectious diseases: A leading threat to public and wildlife heath

Why do diseases (such as chytrid) “emerge”?

Emerging infectious diseases: A leading threat to public and wildlife heath

Why do diseases (such as chytrid) “emerge”?

1) Because disease has expanded its range (“novel”)

Summary

- Herps are heavily parasitized by all sorts of things
- Effects vary
  – Death
  – Reduced fitness
  – No effect
- Massive outbreaks tied to environmental change

Disease in Herps

- Overview of disease-causing agents
  - Bacteria and viruses
  - Internal parasites
  - External parasites
- Consequences of infection